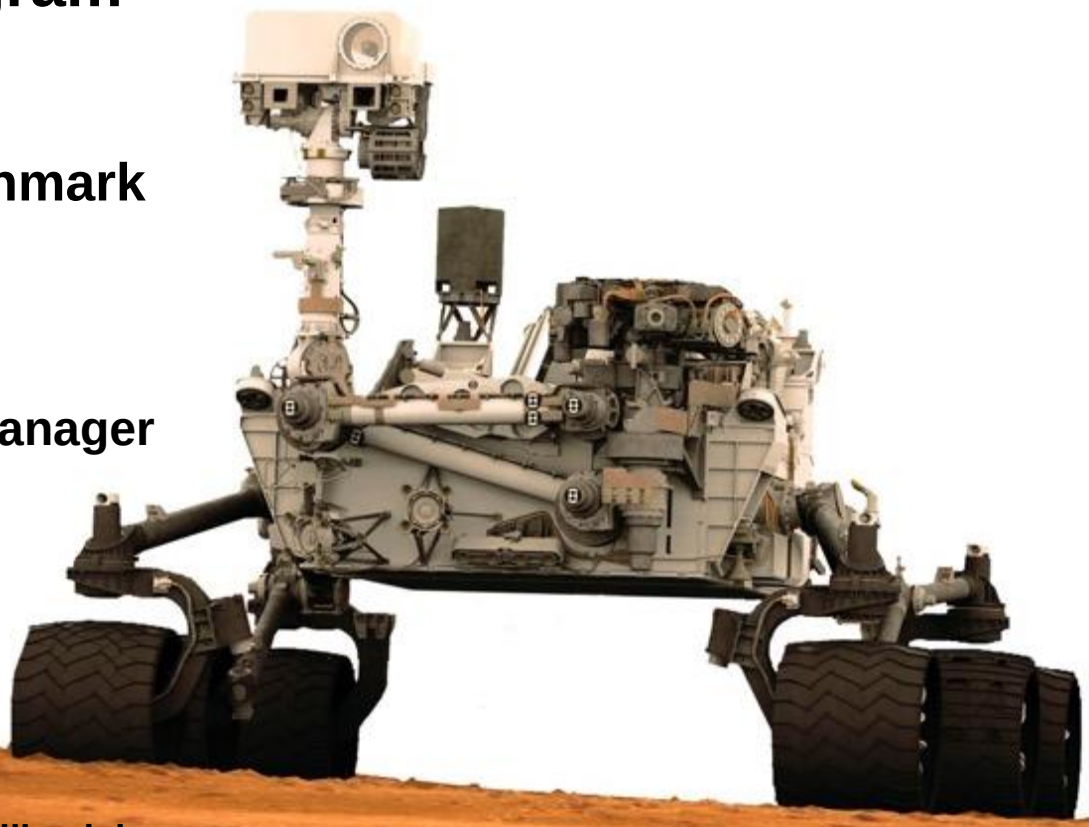
Jet Propulsion Laboratory
California Institute of Technology

JPL and NASA's Mars Exploration Program

Technical University of Denmark
August 17th, 2017

Søren Nørvang Madsen
Mars 2020 Mission Payload Manager

NASA Jet Propulsion Laboratory
California Institute of Technology



Acknowledgement:
Several JPL'ers graciously provided charts for this talk, including: Sarah Milkovich, Mallory Lefland, John McNamee, Fuk Li, Nora Mainland.

From Caltech students testing rockets to exploring the planets in our lifetime

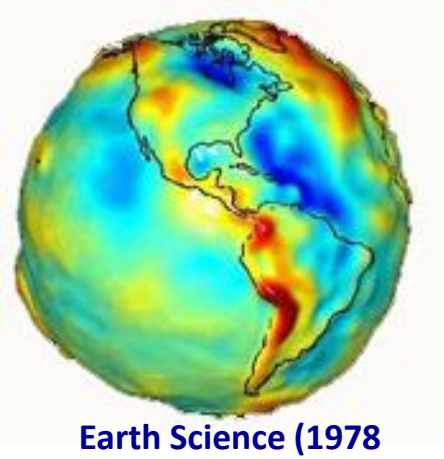
Caltech students (1936)

Missiles (1940s)

Explorer 1 (1958)

Mars Exploration Rovers (2004 – present)

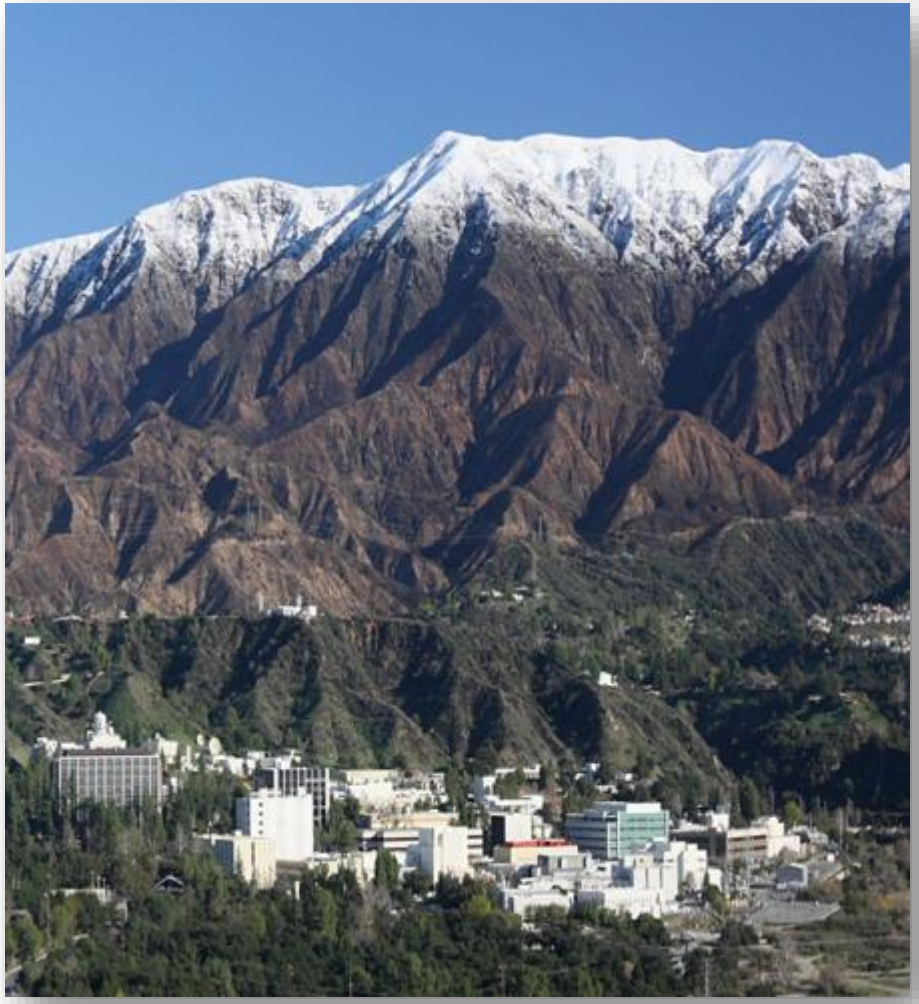
Spitzer Space Telescope (2004 – present)



Earth Science (1978 – now)

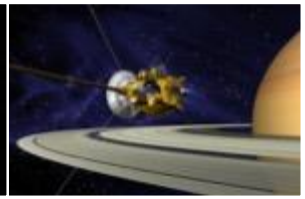
JPL is part of NASA and Caltech

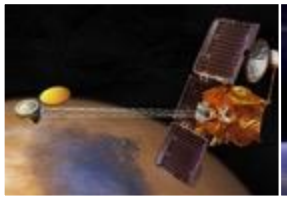
- Federally-funded (NASA-owned) Research and Development Center (FFRDC)
- University Operated (Caltech)
- $2.3B Business Base
- 5,600 Employees
- 167 Acres (includes 12 acres leased for parking)
- 139 Buildings; 36 Trailers



18 Spacecraft and 10 instruments Across the Solar System and Beyond


Two Voyagers (1977)


Cassini (1997)


Mars Odyssey (2001)


Jason 2 (2008)

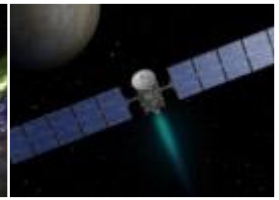

GRACE (2002)


Opportunity (2003)


Spitzer (2003)


Mars Reconnaissance Orbiter (2005)

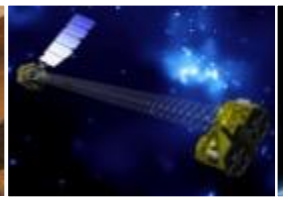

CloudSat (2006)


Dawn (2007)


NEOWISE (2009)

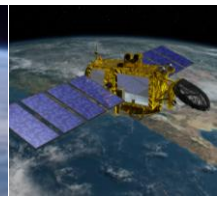

Juno (2011)


Curiosity (2011)


NuSTAR (2012)


OCO-2 (2014)


SMAP (2015)


Jason 3 (2016)

Instruments

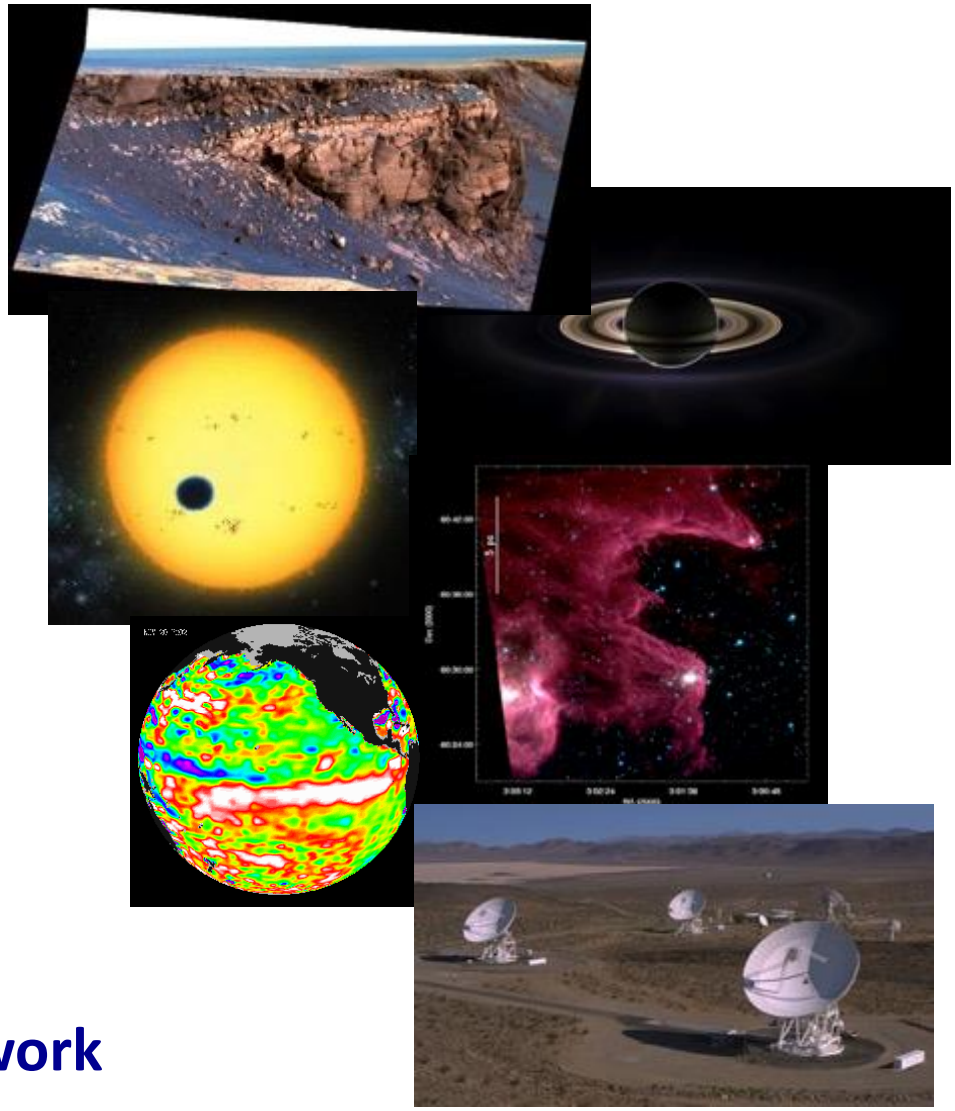
Earth Science

- MISR (1999)
- AIRS (2002)
- TES (2004)
- MLS (2004)
- ASTER (2009)
- OPALS (2014)
- RapidScat (2014)

- MARSIS (2003)
- MIRO (**2004**)
- **Diviner (2004)**

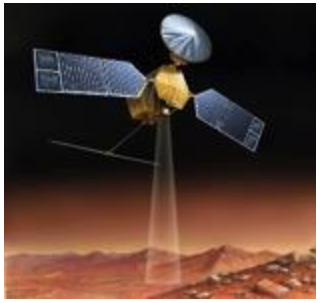
JPL's mission for NASA is *robotic* space exploration

- Mars
- Solar system
- Exoplanets
- Astrophysics
- Earth Science
- Interplanetary network



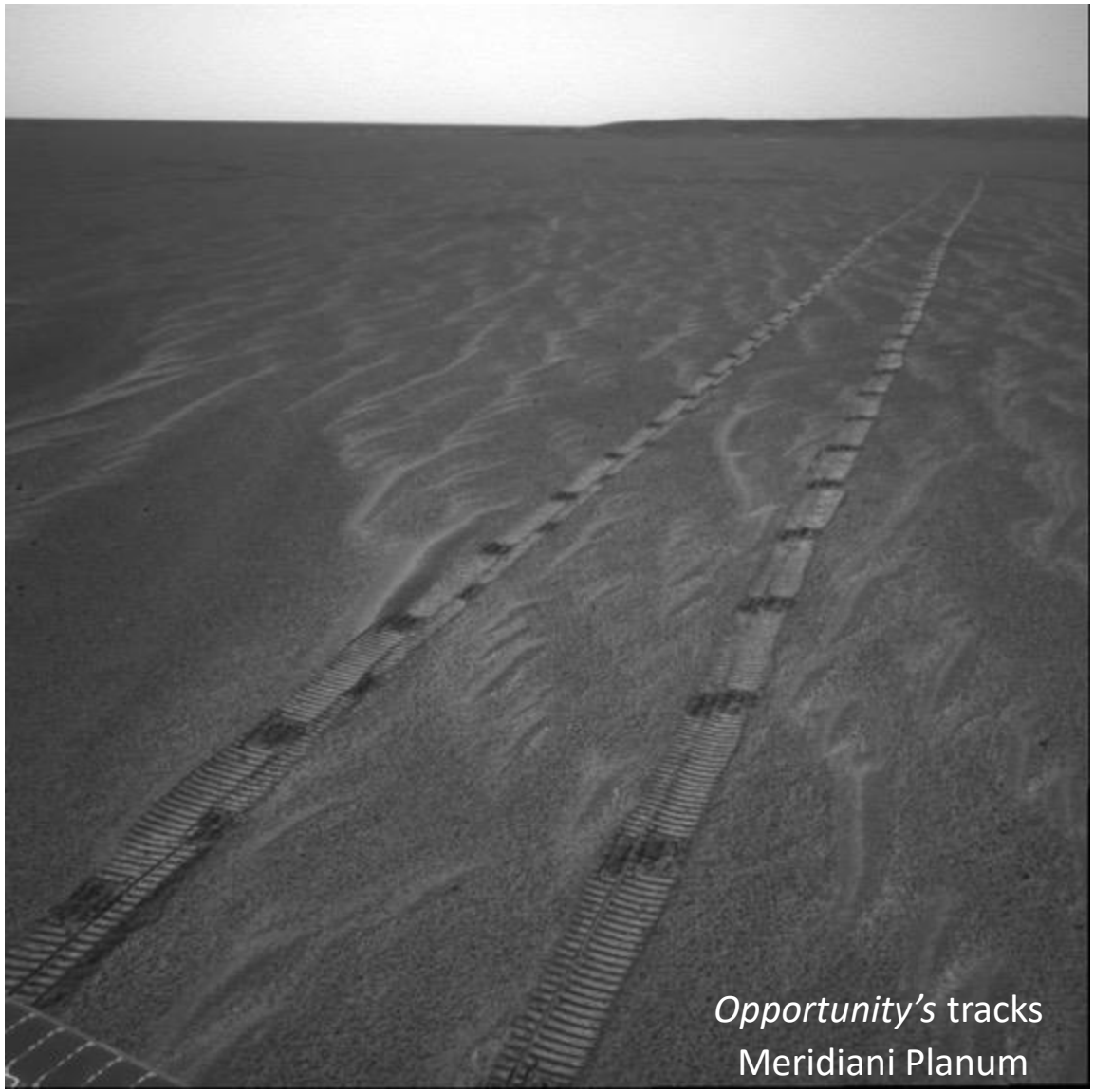
Now: A continuous robotic presence on and in-orbit around Mars

2001 Mars Odyssey



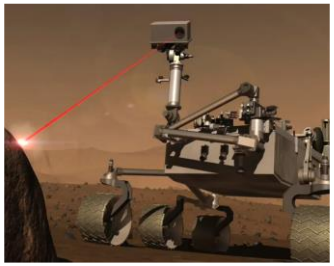
Mars Reconnaissance Orbiter

Mars Express (ESA)



Opportunity's tracks
Meridiani Planum

Opportunity

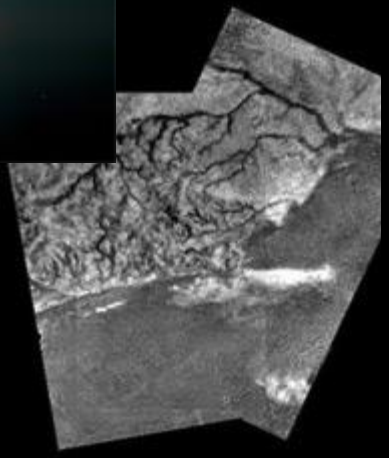


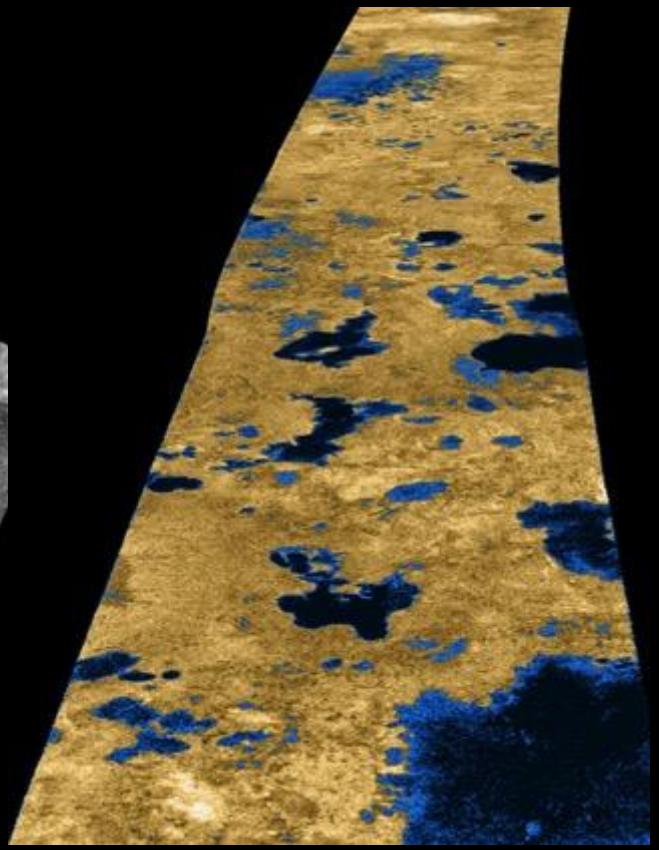
Curiosity

"Do not go where the path may lead, go instead where there is no path and leave a trail"

--- Ralph Waldo Emerson

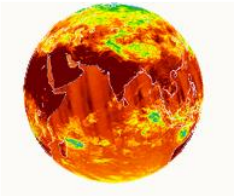
Cassini/Huygens studies Saturn, Enceladus' geysers, and Titan's lakes



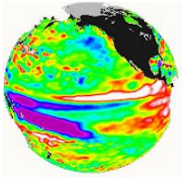


Multiple Ways to View a Changing Earth

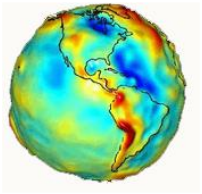
Satellites



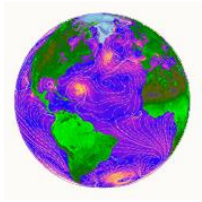
AIRS – atmospheric temperature



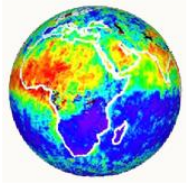
JASON – sea surface height



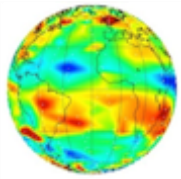
GRACE – gravity



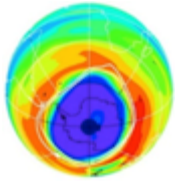
QUIKSCAT – wind



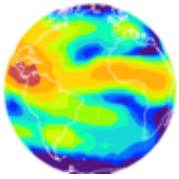
MISR - aerosols



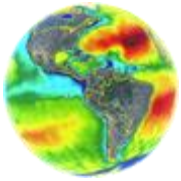
TES – trace gas



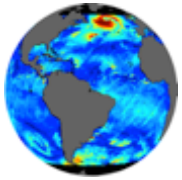
MLS – ozone layer



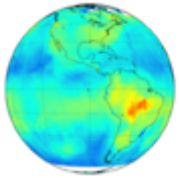
CLOUDSAT – water content



Aquarius - sea surface salinity



RapidScat – wind

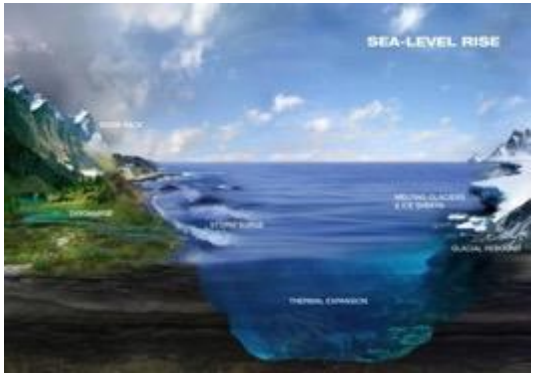


OCO-2 – Carbon Dioxide

Will sea level continue to rise at the current rate?

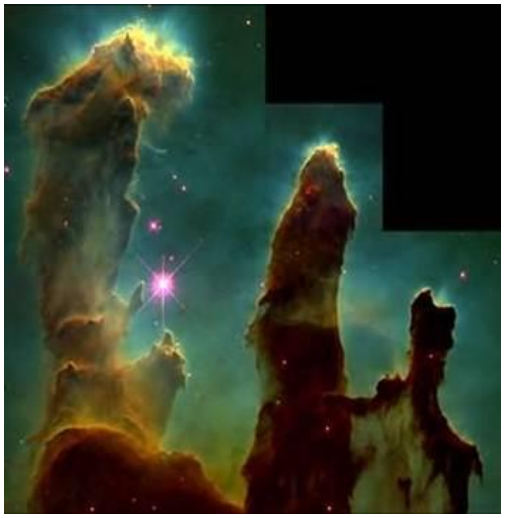
Will water availability change in the future?

How are carbon storage and biodiversity changing?



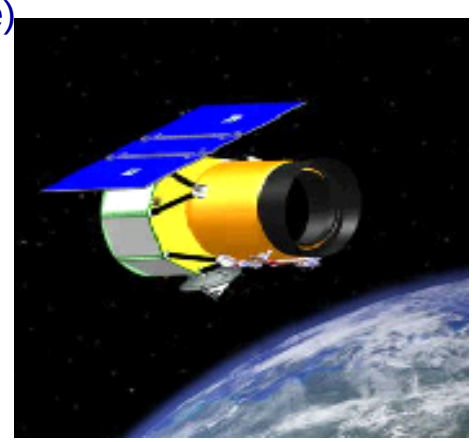
How can we better prepare for extreme events such as earthquakes, floods and volcanoes?

Astrophysics Missions

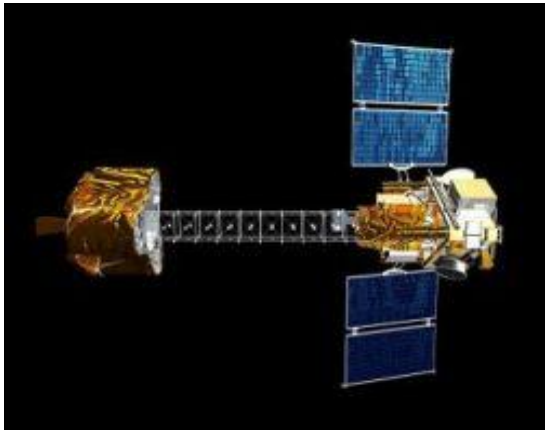


Wide Field/Planetary Camera (on Hubble)

Spitzer Space Telescope

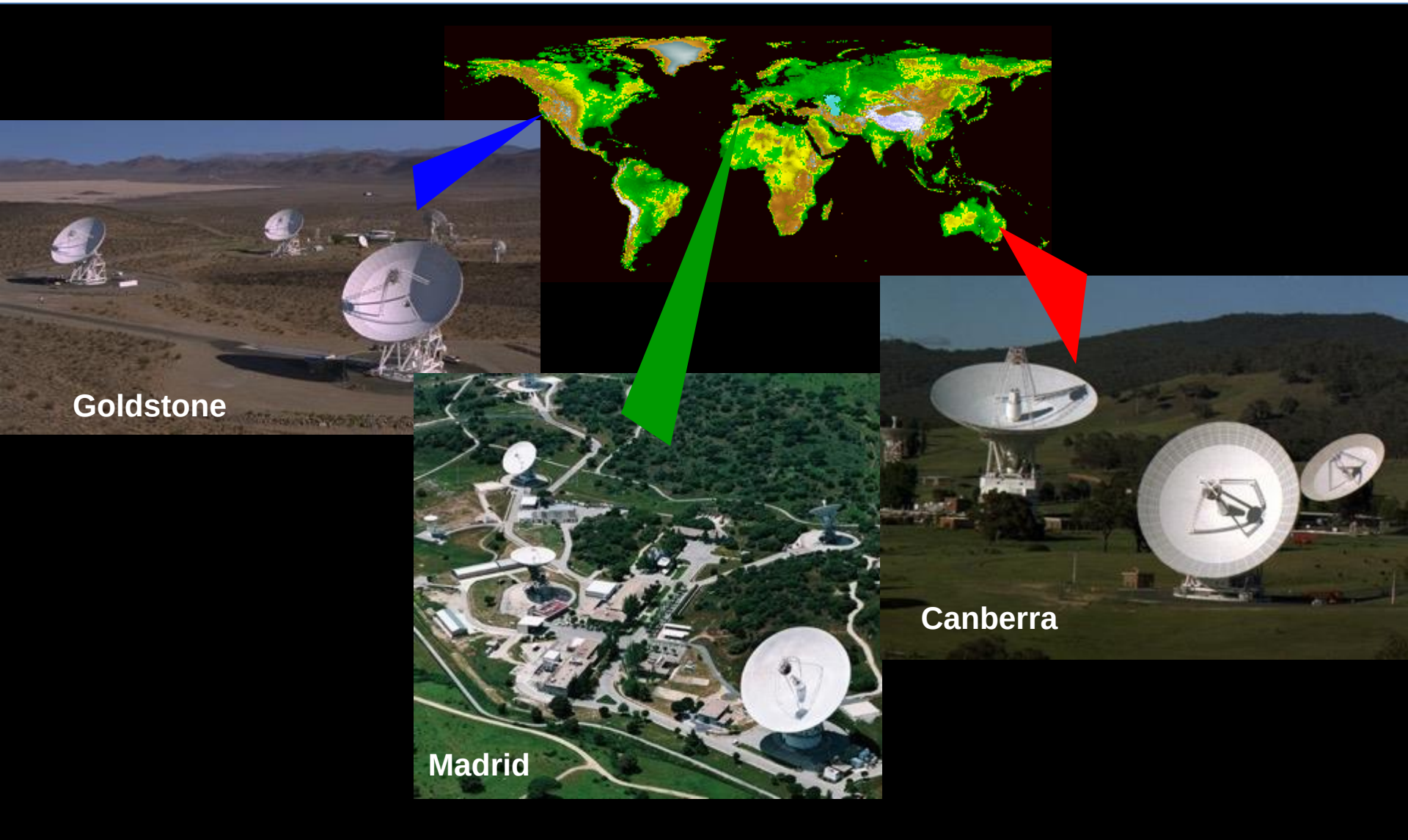


Near Earth Object Wide-field Infrared Explorer (NEOWISE)

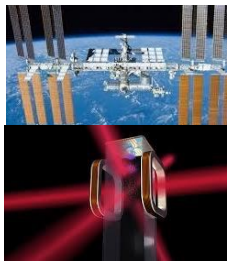


Nuclear Spectroscopic Telescope Array (NuSTAR)

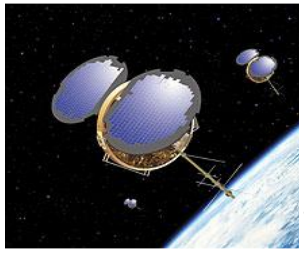
Deep Space Network (DSN)



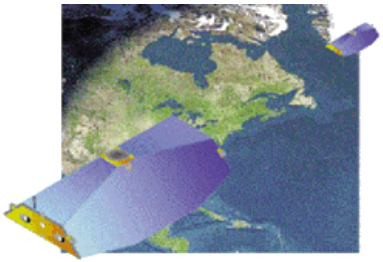
Upcoming and Planned Missions



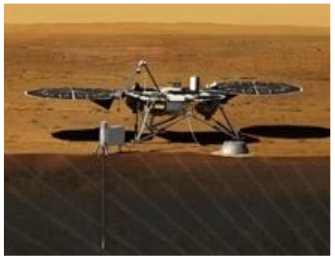
Cold Atom Lab
2017



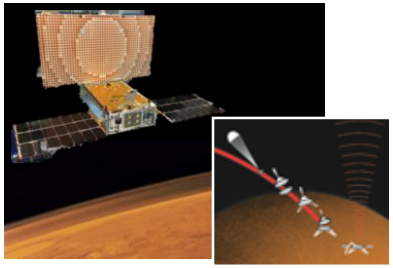
COSMIC-2
2018



GRACE-FO
2018

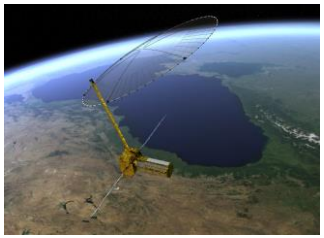


InSIGHT
2018

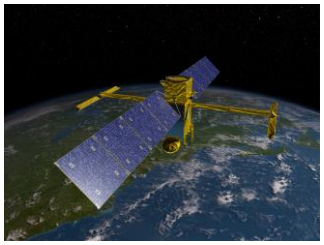


MarCo
2018

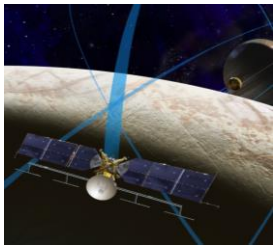
Mars 2020



NISAR 2021



SWOT 2021



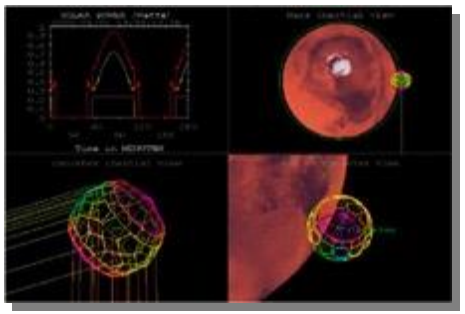
Europa Clipper 2022

WFIRST 2022

Psyche
2022

End-to-End Capabilities Needed to Implement Missions

Project Formulation - Team X

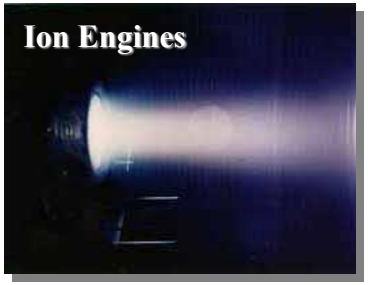


Mission Design

Mars Rovers

Large Structures-SRTM

Integration and Test



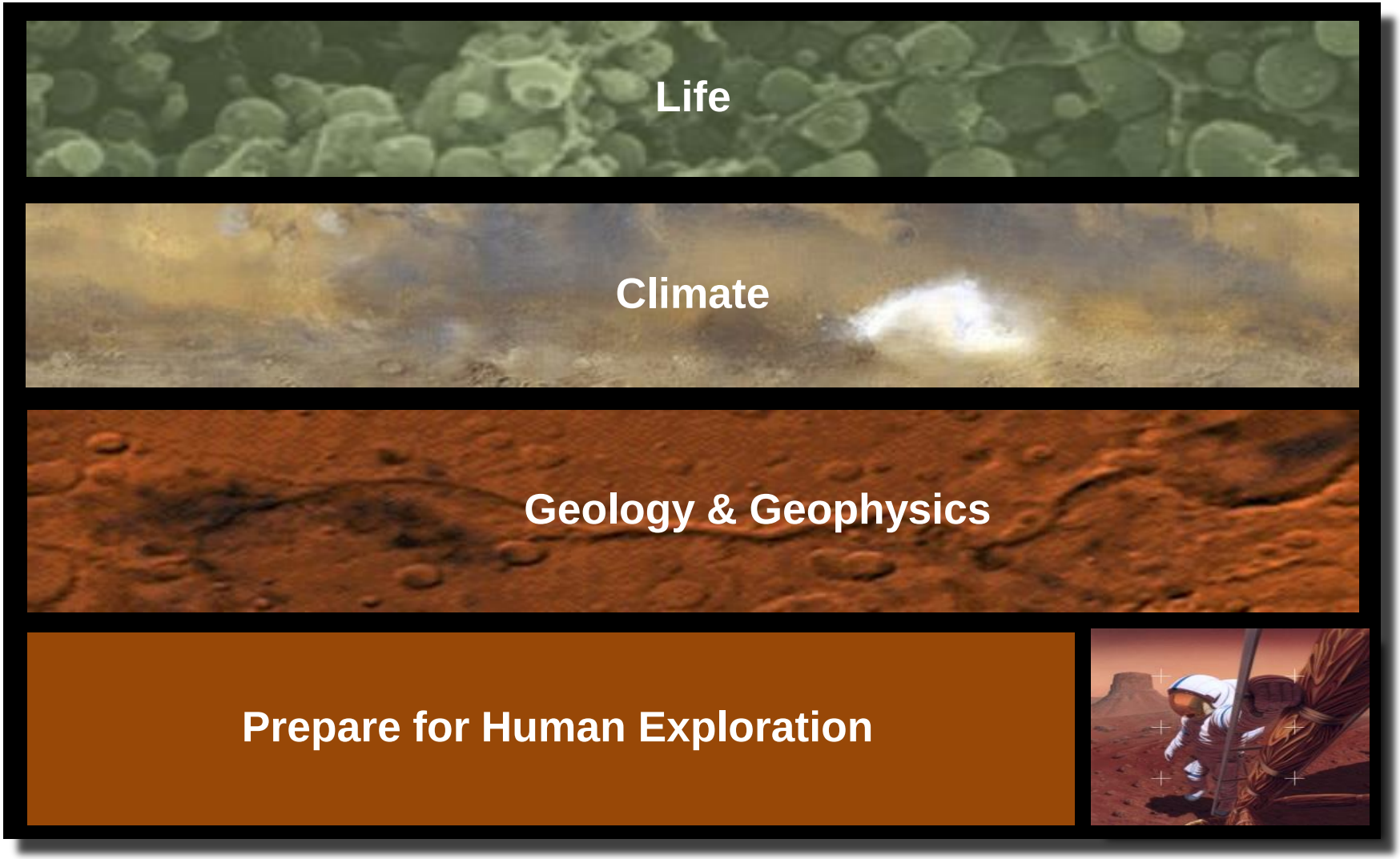
Spacecraft Development

Environmental Test

Real Time Operations

Scientific Research

Mars Exploration Program Science Goals



Mars Exploration Program

Operational

2001-2007

Odyssey

MRO

Mars Express Collaboration

2009

2011

2013

MAVEN Aeronomy Orbiter

2018

2020 & Beyond

Mars Orbiter (proposed)

MER

Phoenix (completed)

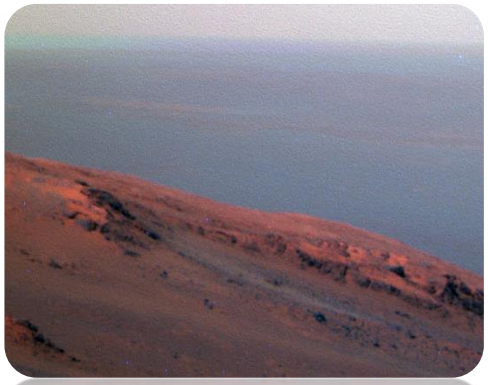
Mars Science Laboratory

InSIGHT

'20 Mars Rover Mission

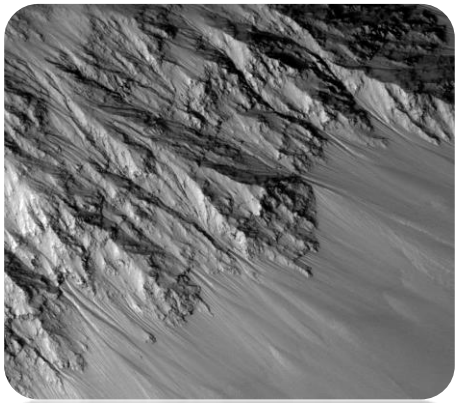
Mars Exploration Program Highlights

Opportunity: Journey to Perseverance Valley

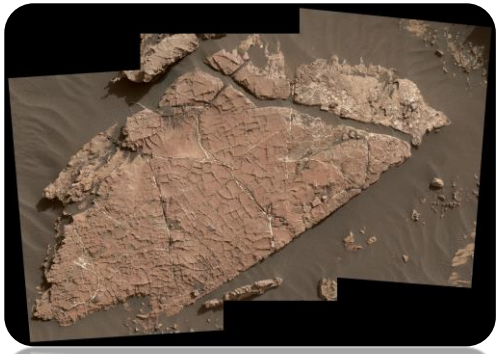


MRO: >50,000 orbits Completed Global 6m Resolution Imagery

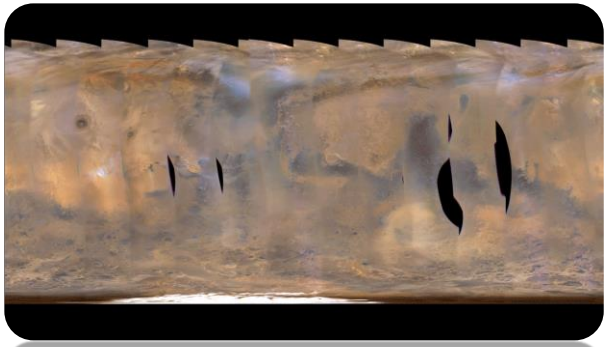
MRO: Continuing Observations of Recurring Slope Lineae



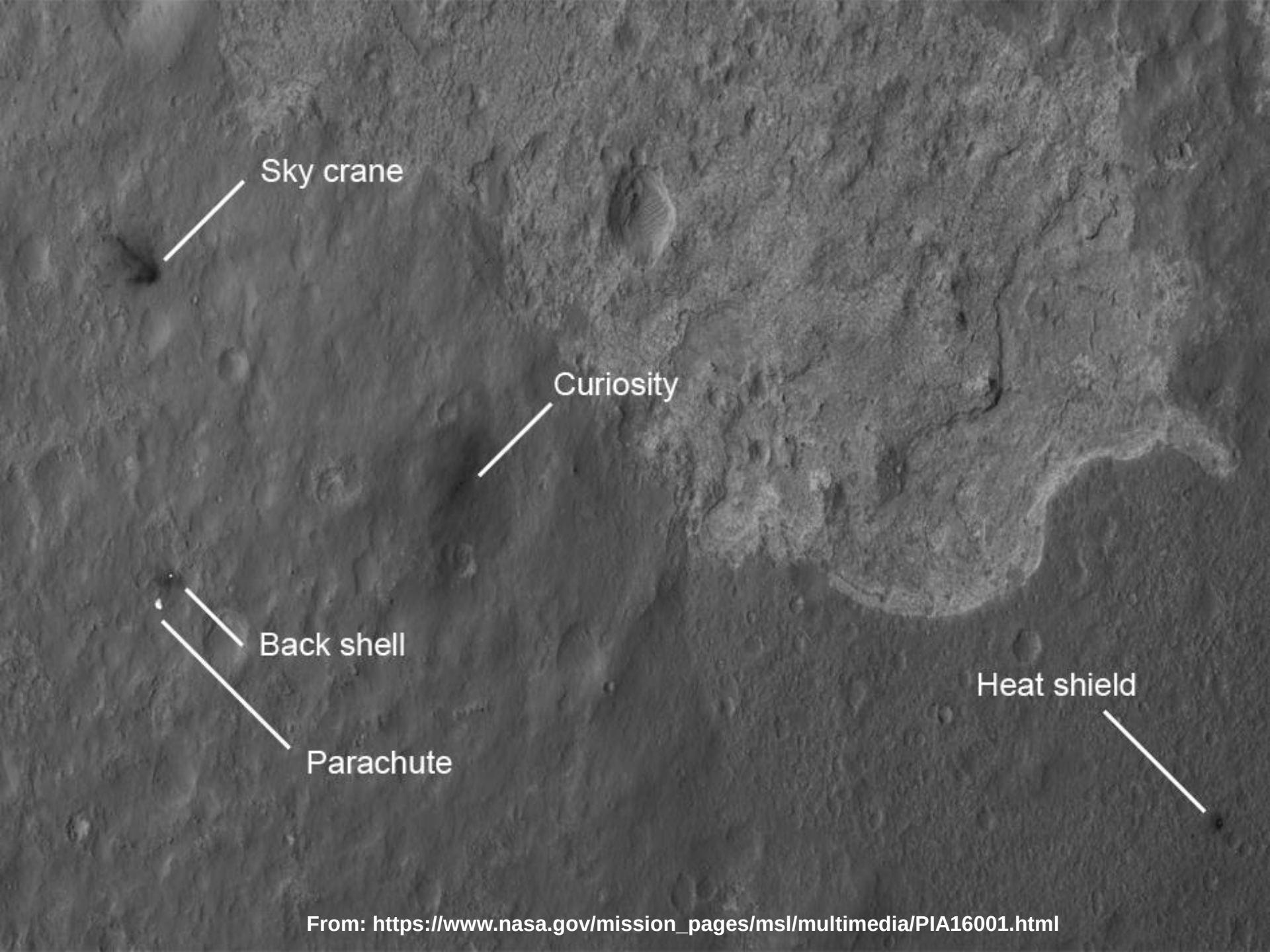
Curiosity: >4.5 years since landing



MAVEN Tracks Back-to-back Regional Storms



Mars 2020 Landing Site Finalists



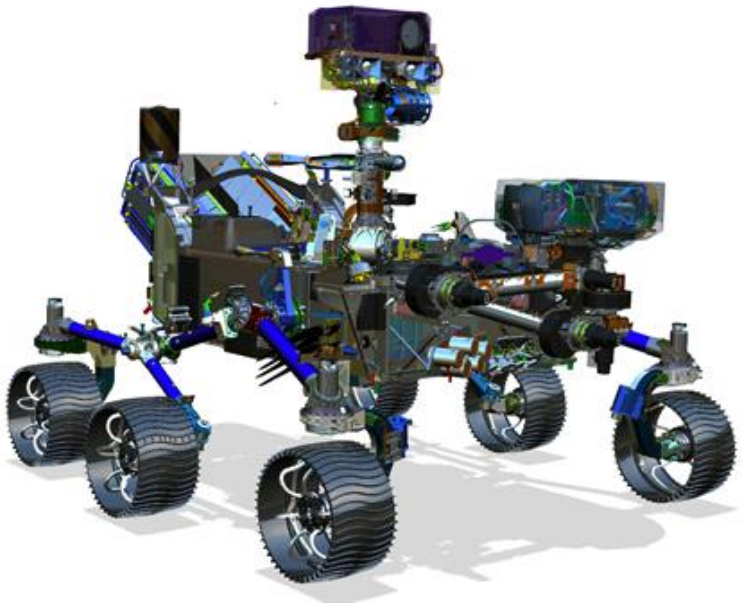
From: https://www.nasa.gov/mission_pages/msl/multimedia/PIA16001.html

Project Overview

Jet Propulsion Laboratory
California Institute of Technology

Salient Features

- *Category: 1*
- *Risk Class: A-tailored*
- *Directed, JPL in-house implementation*
- *High heritage MSL design*
- *Modifications only as necessary to accommodate new payload and Sampling / Caching System (SCS)*
- *Planetary Protection Category V per Program direction*



Science

A. Characterize the…geologic record…of an astrobiologically-relevant ancient environment.

B. Perform…astrobiologically relevant investigations.

C. Assemble rigorously documented and returnable cache…

D. Contribute to the preparation for human exploration of Mars…

Mission Overview

Jet Propulsion Laboratory
California Institute of Technology

LAUNCH

- Atlas V 541 vehicle
- Launch Readiness Date: July 2020
- Launch window: July/August 2020

CRUISE/APPROACH

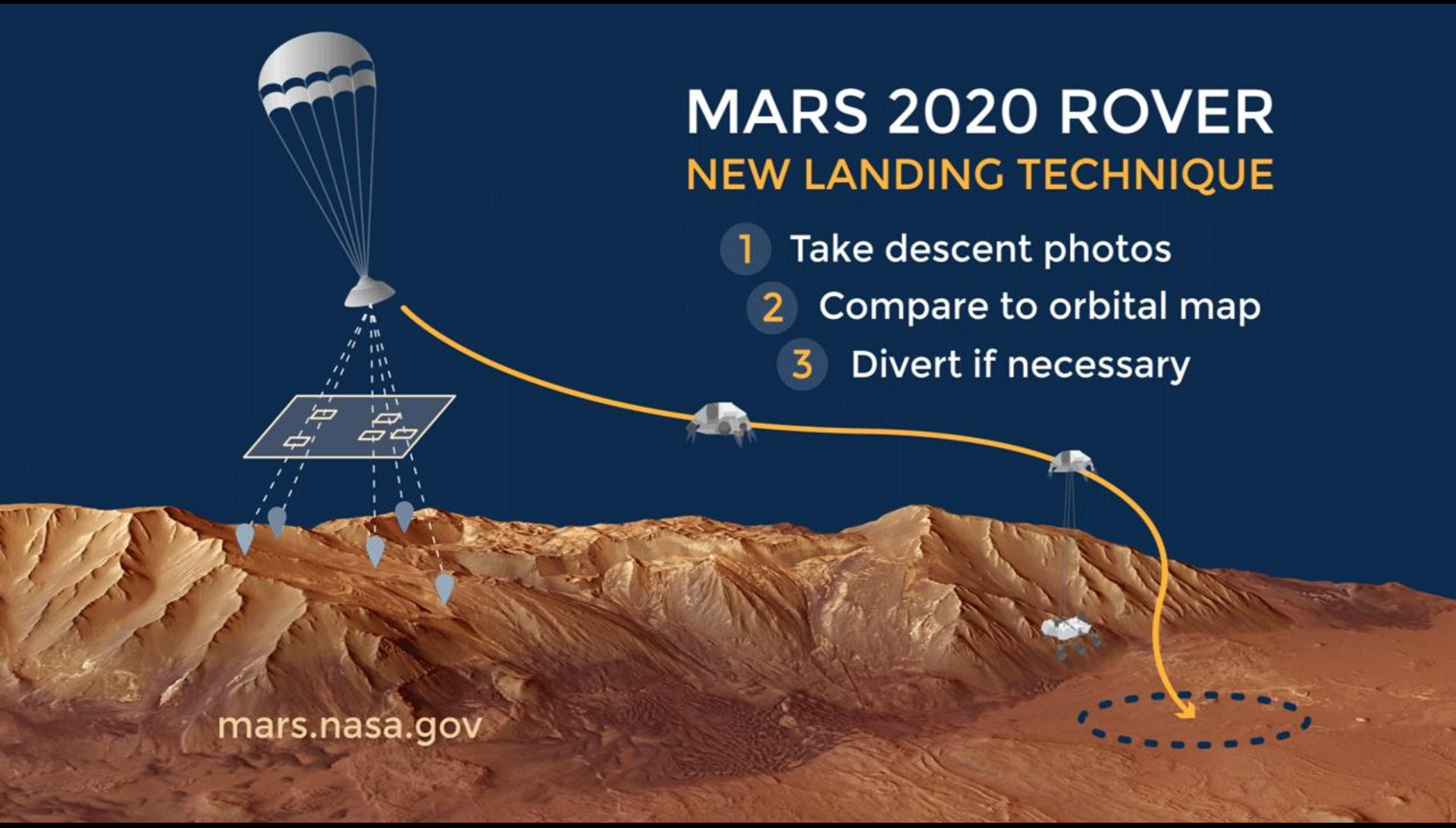
- ~7 month cruise
- Arrive Feb 2021

ENTRY, DESCENT & LANDING

- MSL EDL system (+ Range Trigger and Terrain Relative Navigation): guided entry and powered descent/Sky Crane
- 16 x 14 km landing ellipse (range trigger baselined)
- Access to landing sites ±30° latitude, ≤ -0.5 km elevation
- Curiosity-class Rover

SURFACE MISSION

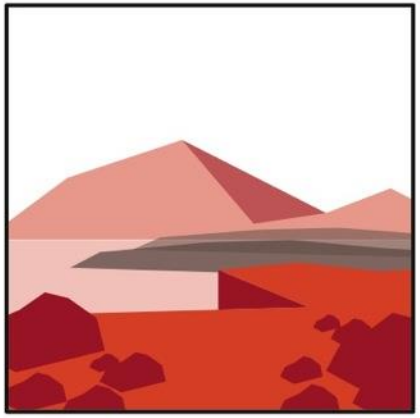
- 20 km traverse distance capability
- Enhanced surface productivity
- Qualified to 1.5 Martian year lifetime
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars


MARS 2020 ROVER
NEW LANDING TECHNIQUE
1 Take descent photos
2 Compare to orbital map
3 Divert if necessary
mars.nasa.gov

Understanding the Possibilities for Life on Mars

Ancient Microbial Life + Human Life

OBJECTIVE A:
Habitability



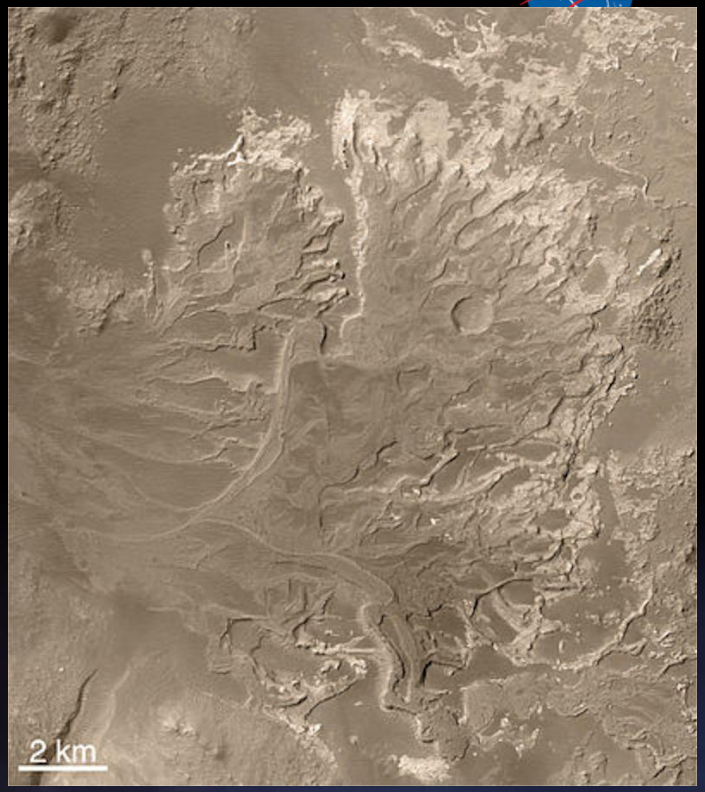
OBJECTIVE B:
Biosignatures

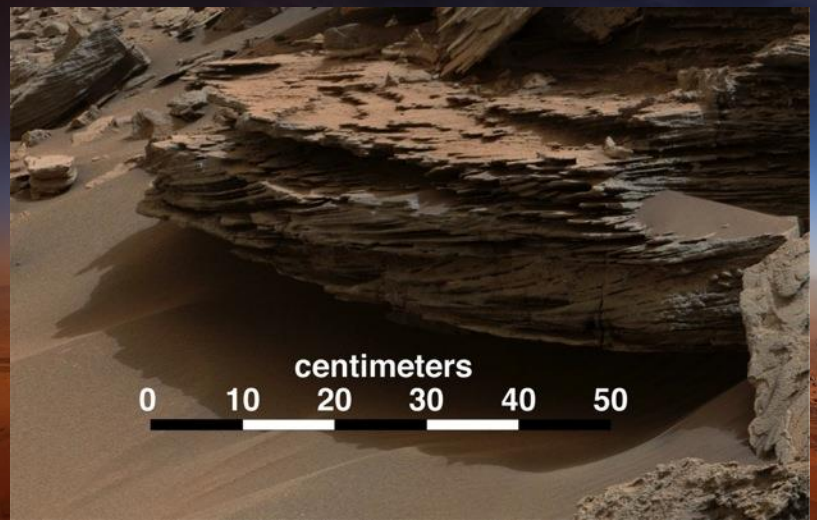
OBJECTIVE C:
Sample Caching

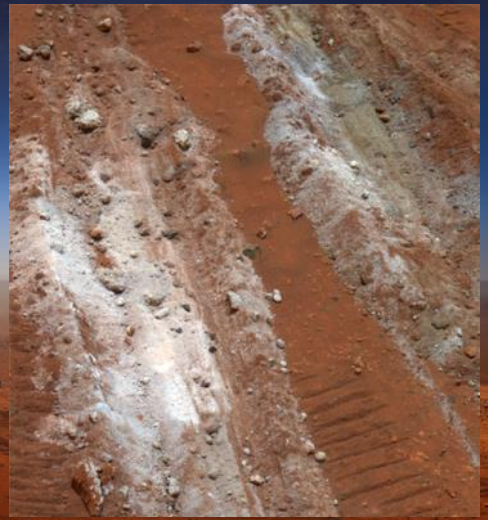
+

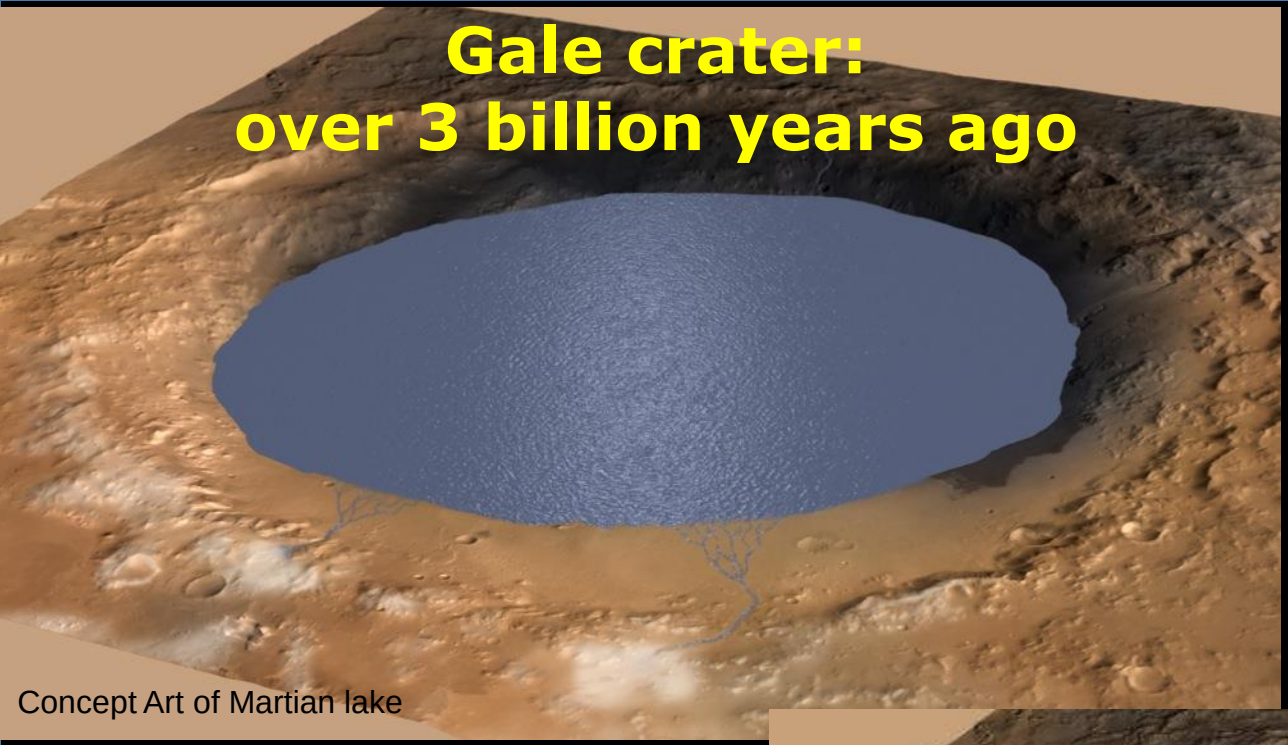
OBJECTIVE D:
Prepare for Humans

Yet, Mars has abundant evidence for ancient water!







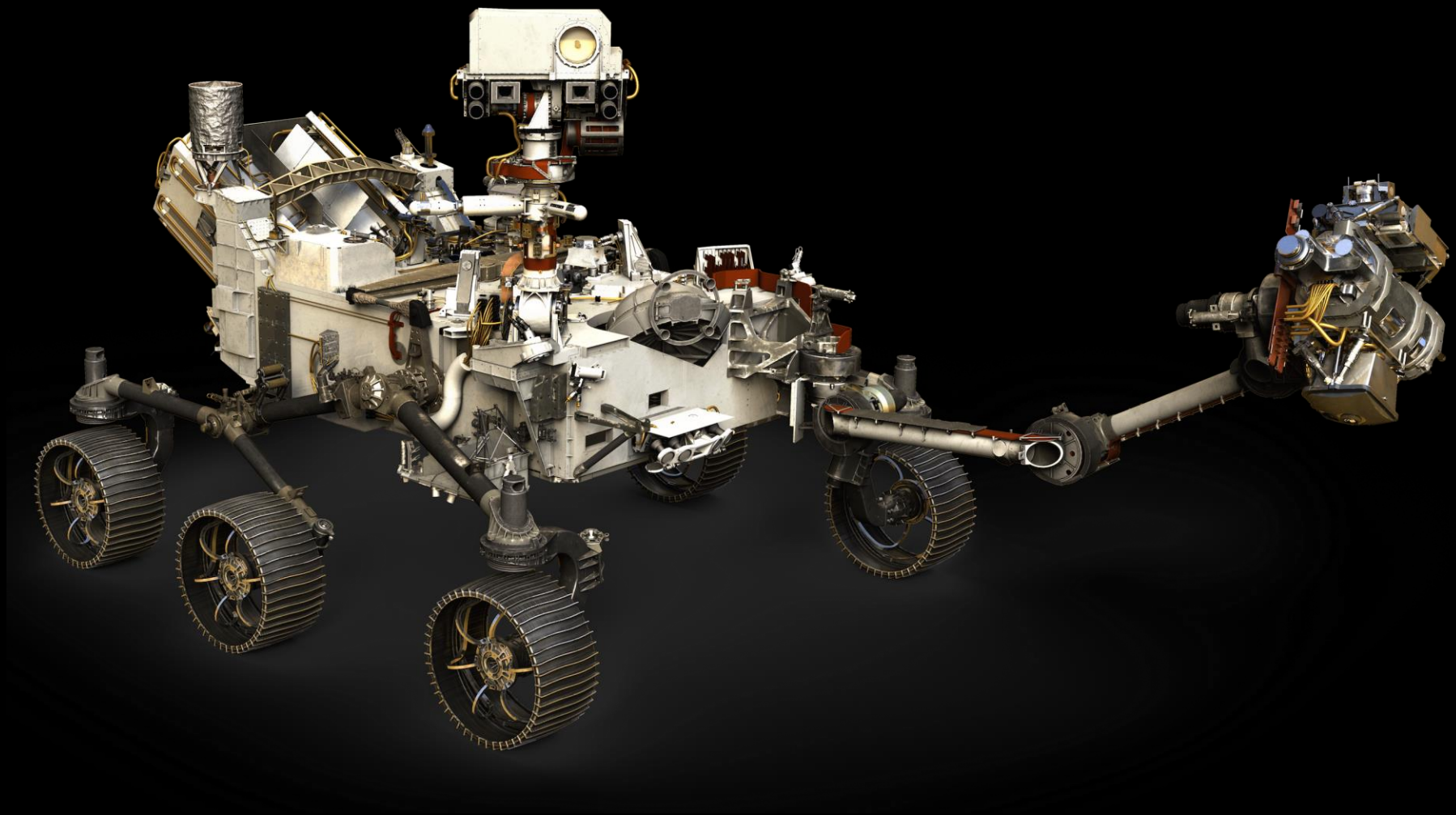


Concept Art of Martian lake

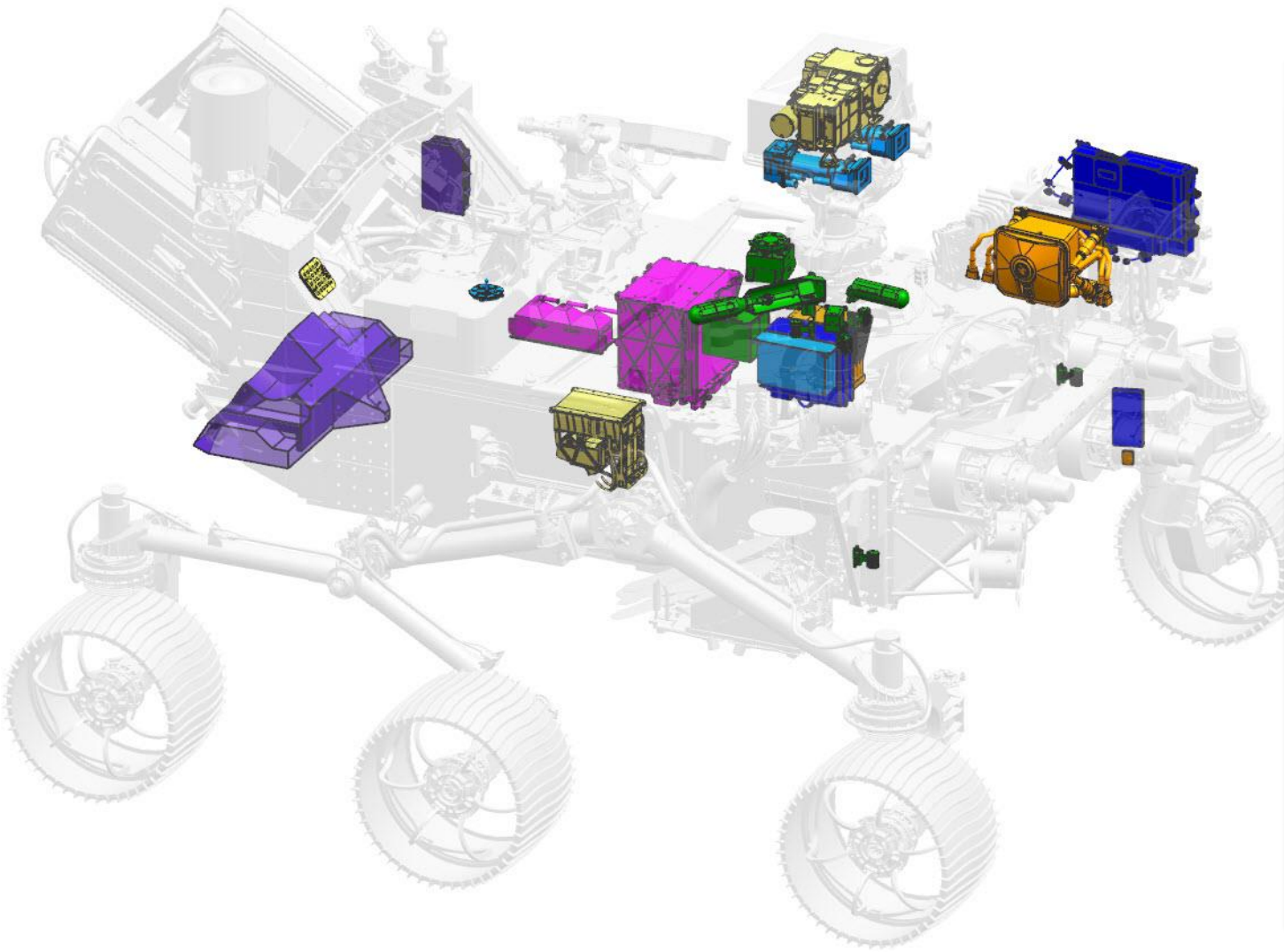
NASA/JPL-Caltech/ESA/DLR/FU Berlin/MSSS

The Mars 2020 Rover:

Seeking Signs of Past Life on Mars

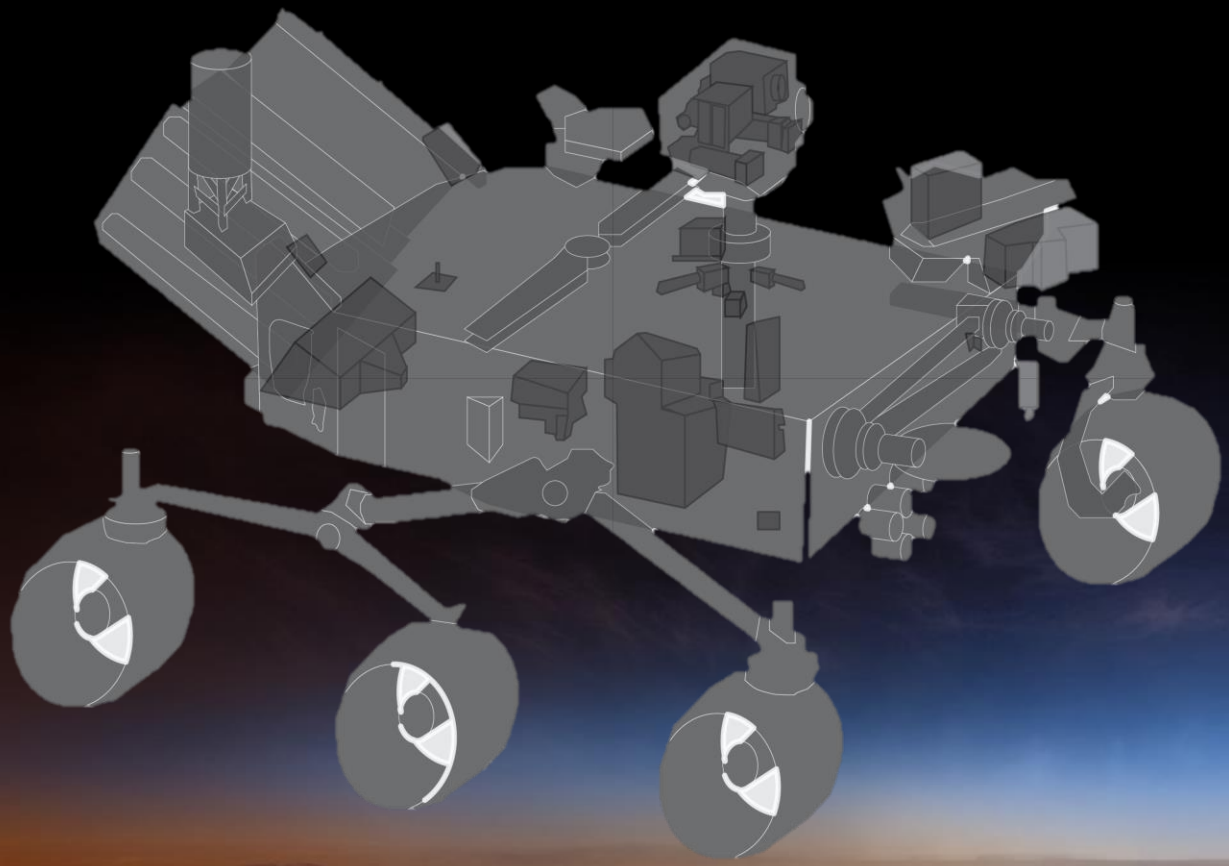


Mars 2020 Payload Family Picture



Instrument Key
Mastcam-Z Stereo Imager
MEDA Mars Environmental Measurement
MOXIE In-Situ Oxygen Production
PIXL Microfocus X-ray fluorescence spectrometer
RIMFAX Ground Penetrating Radar
SHERLOC Fluorescence and Raman spectrometer and Visible context imaging
SuperCam LIBS and Raman

The Mars 2020 Rover:
Robotic Field Geologist + Astrobiologist



New types of instruments to measure fine-scale **mineralogy**, **elemental composition** of rocks for determining **habitability**, detecting **potential biosignatures**

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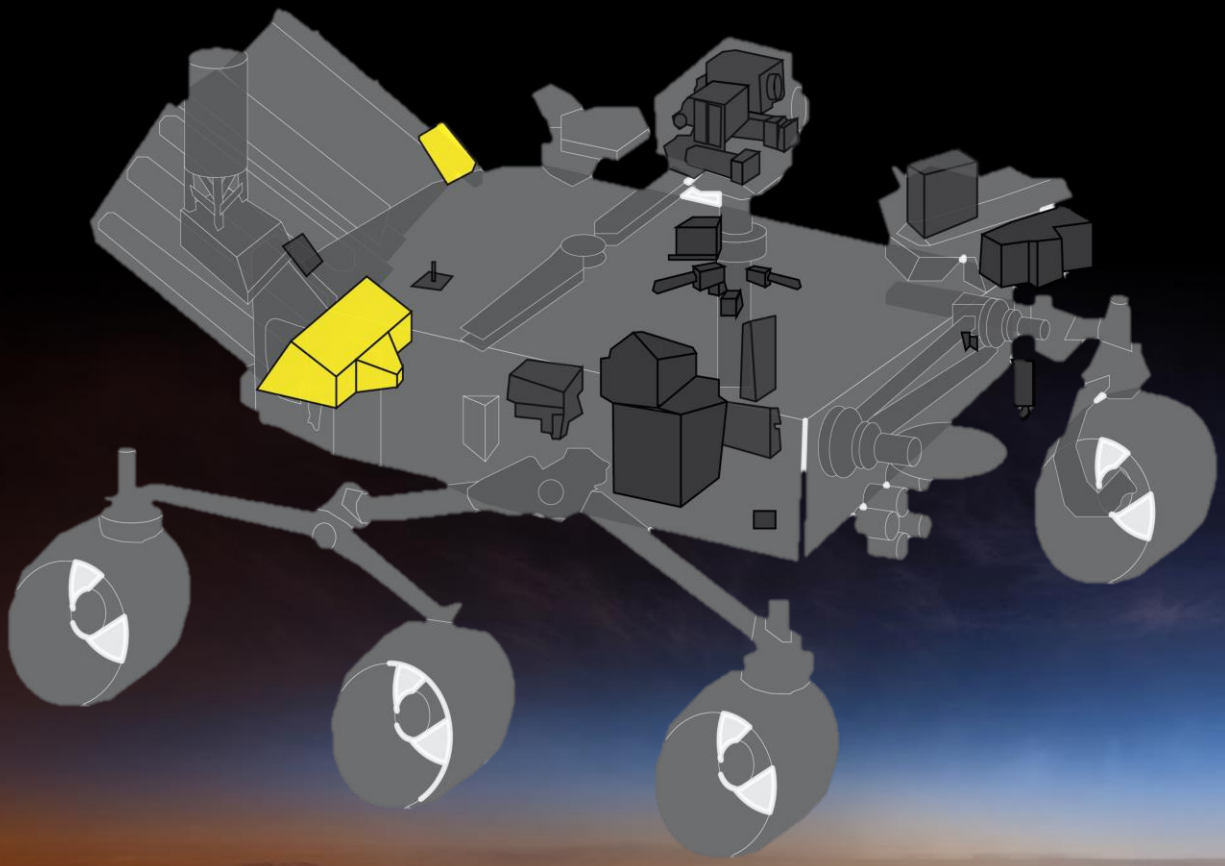
RIMFAX



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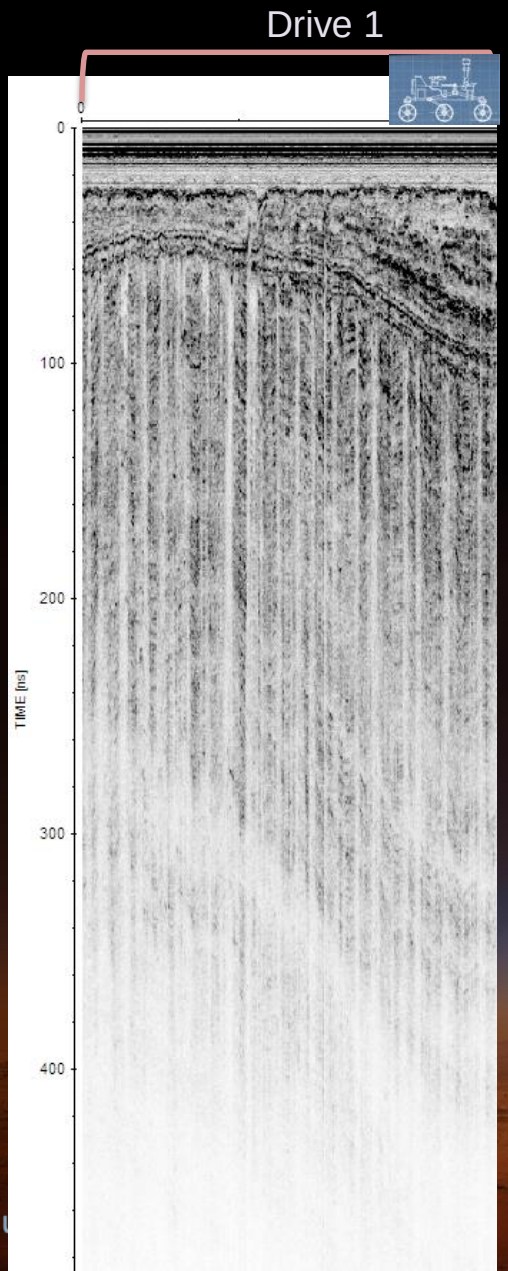
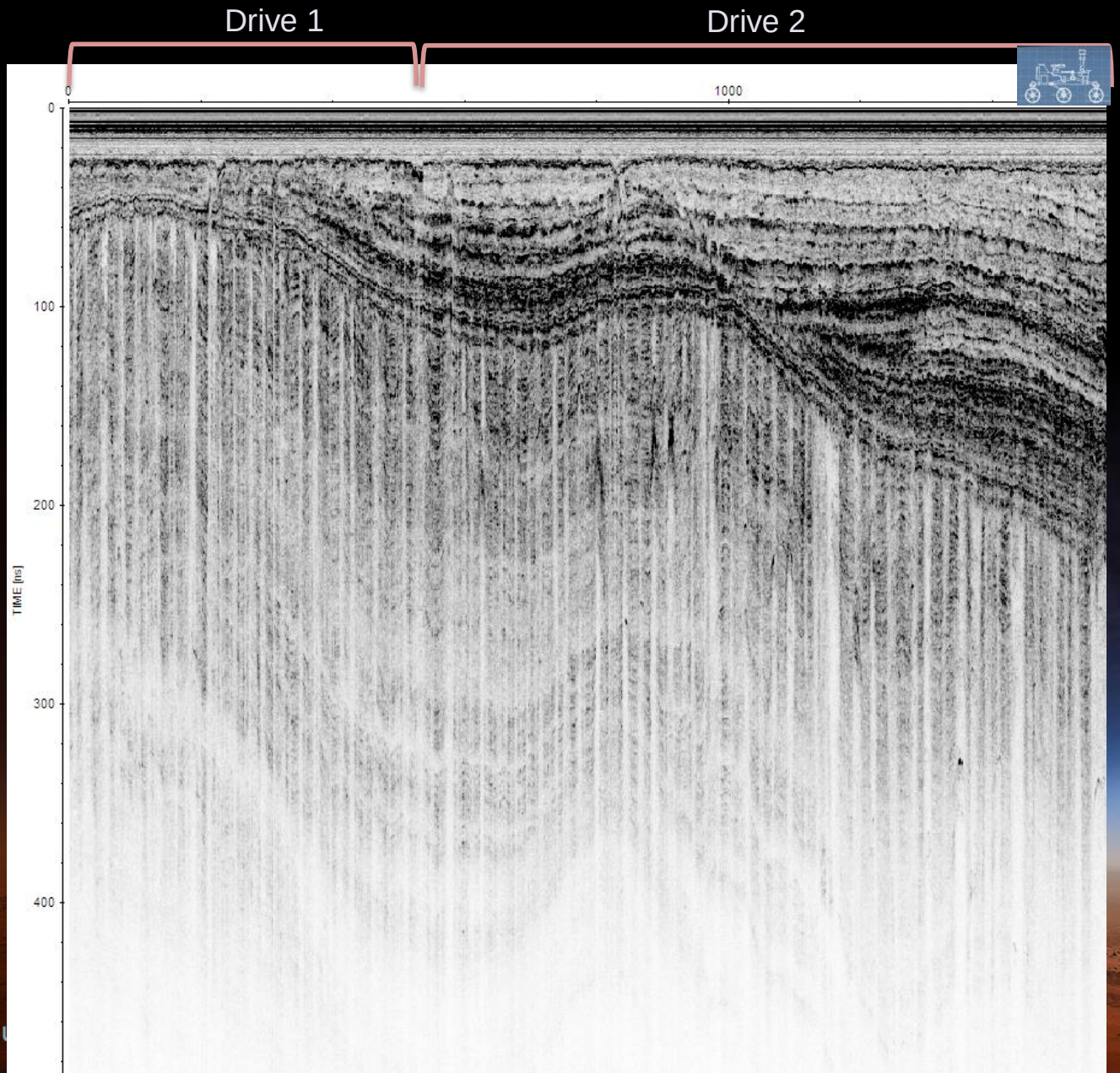
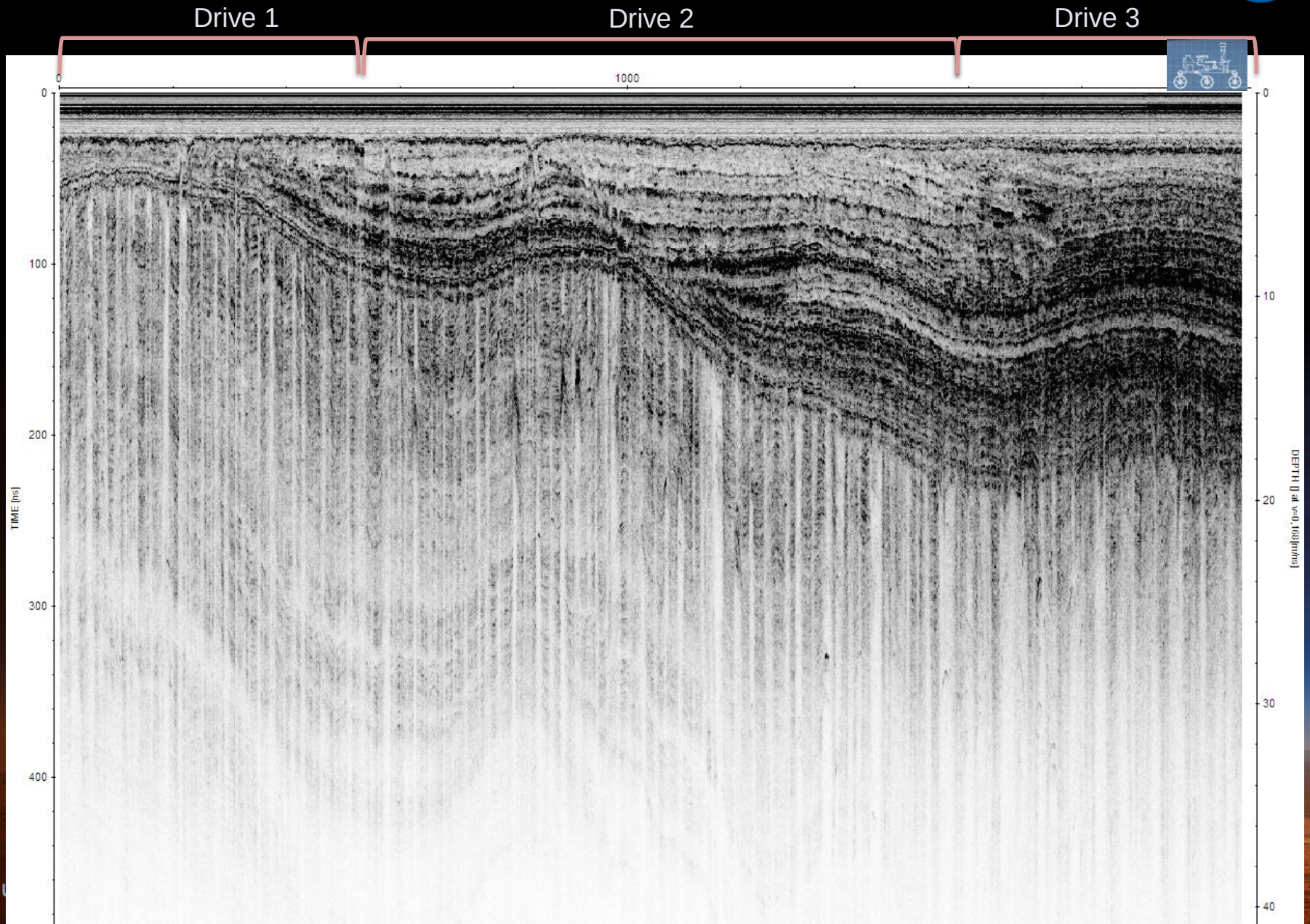
RIMFAX: A View Beneath the Surface



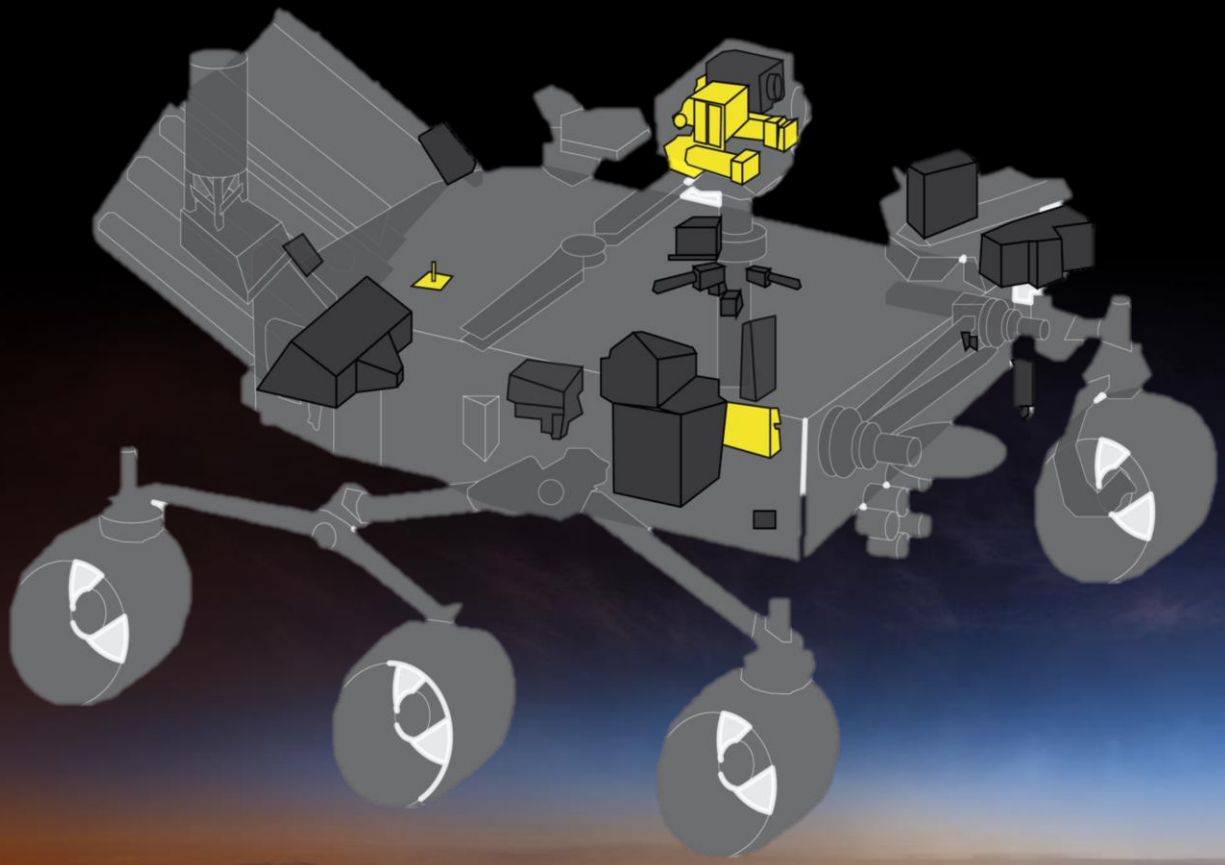
RIMFAX: A View Beneath the Surface



RIMFAX: A View Beneath the Surface



Mastcam-Z



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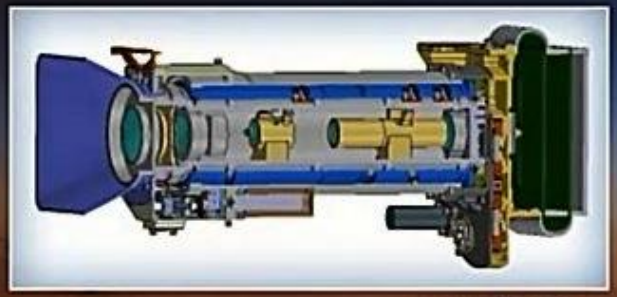
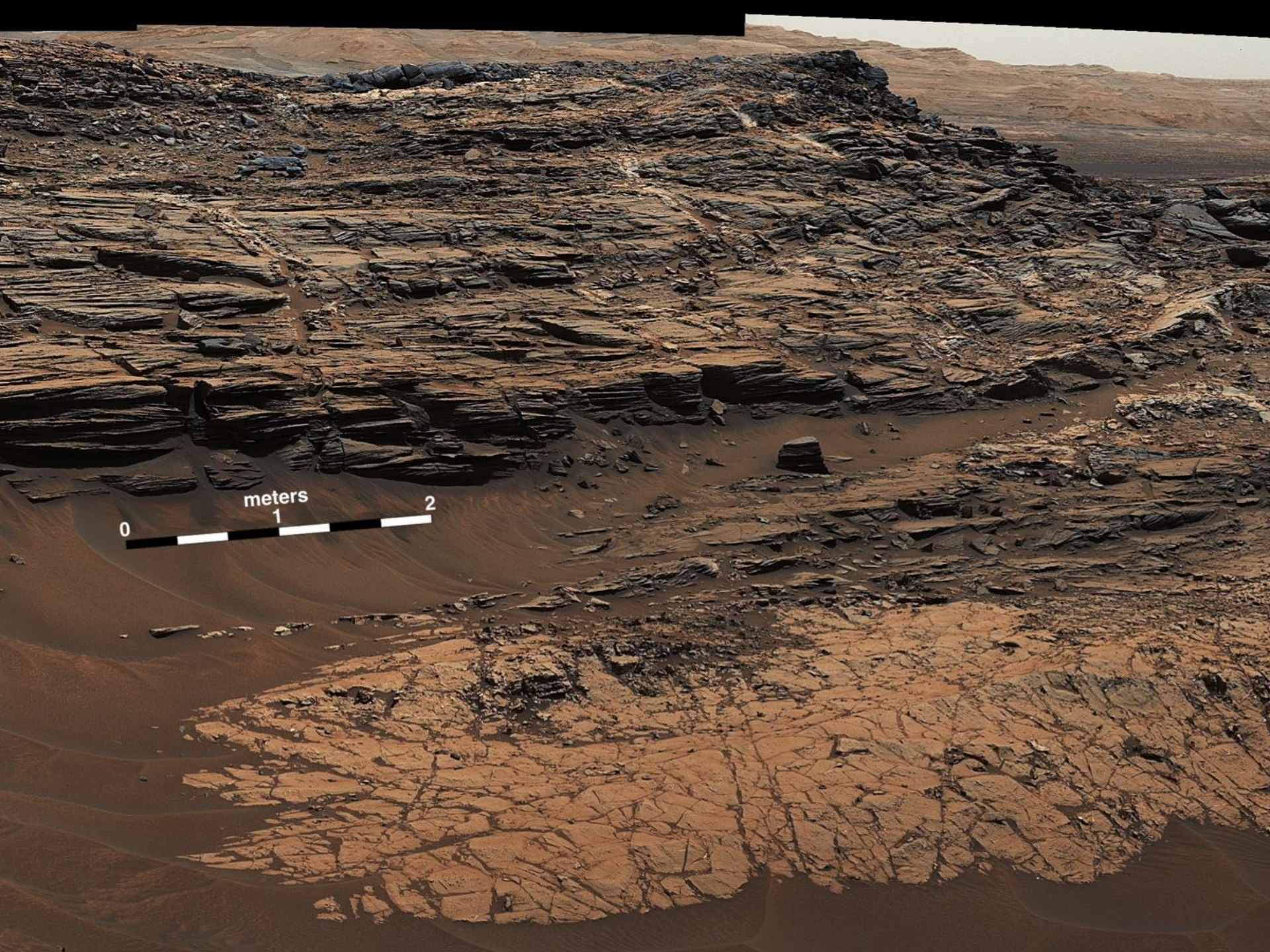
Mastcam-Z

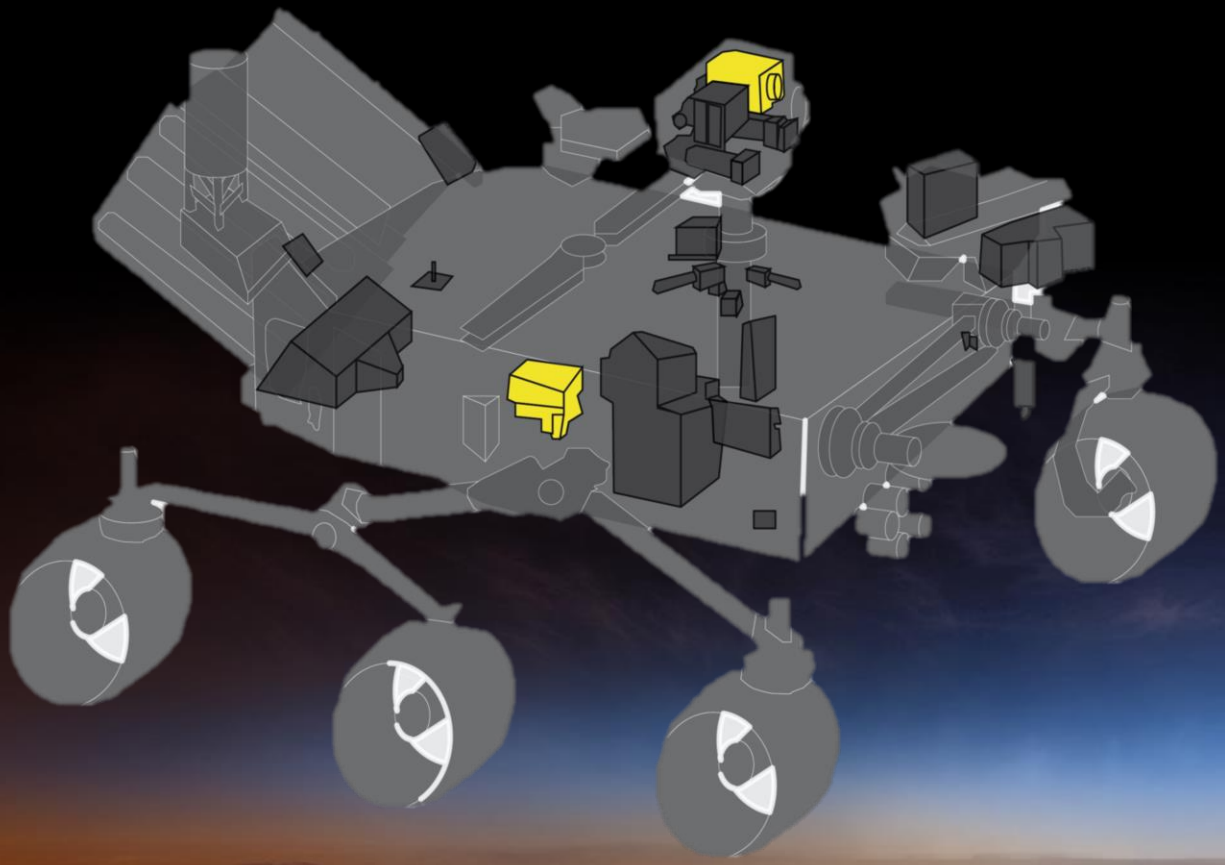
A Geologic, Stereoscopic, and Multispectral Investigation for the NASA Mars-2020 Rover Mission



improved stereo **zoom** camera


meters
0
1
2

SuperCam



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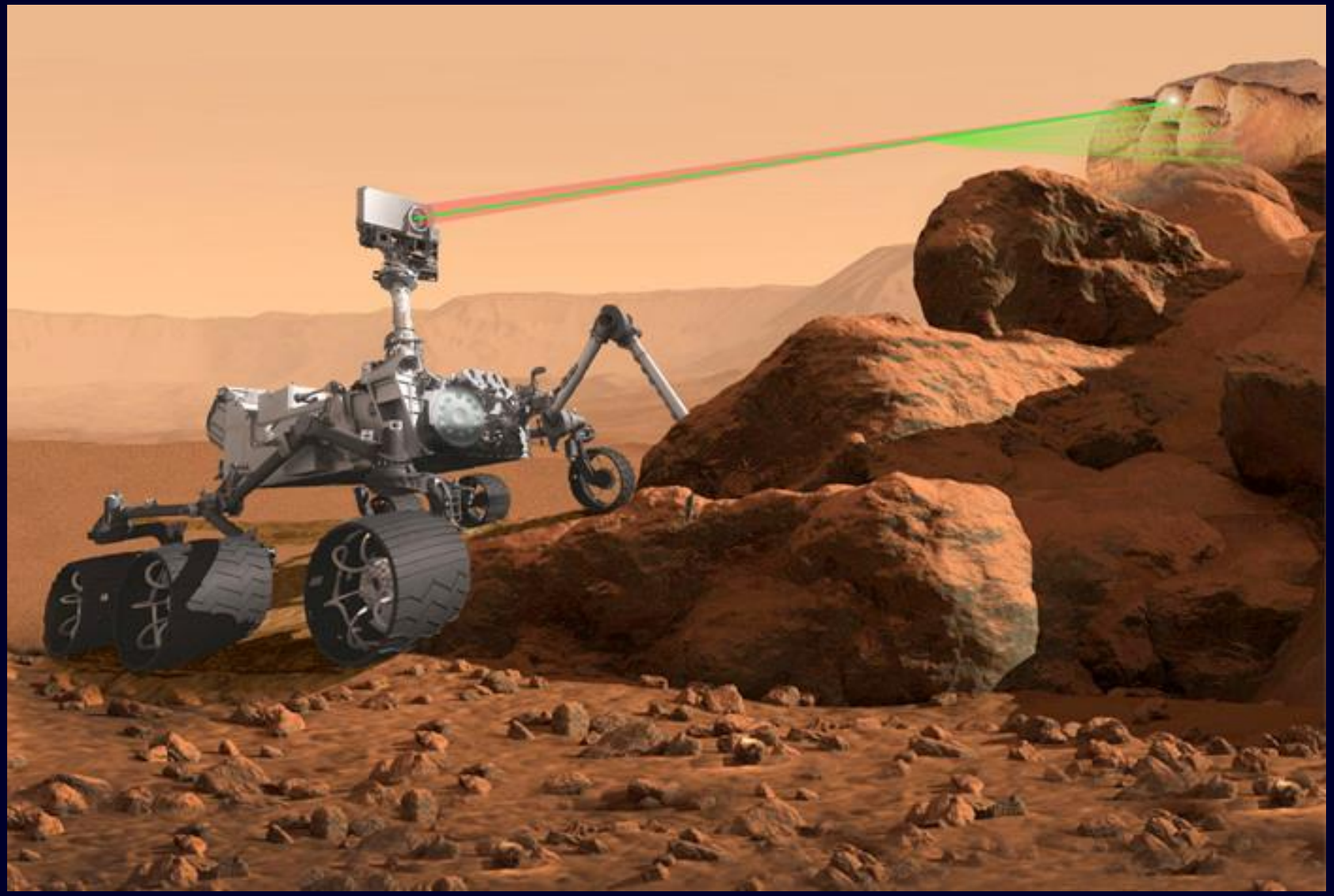
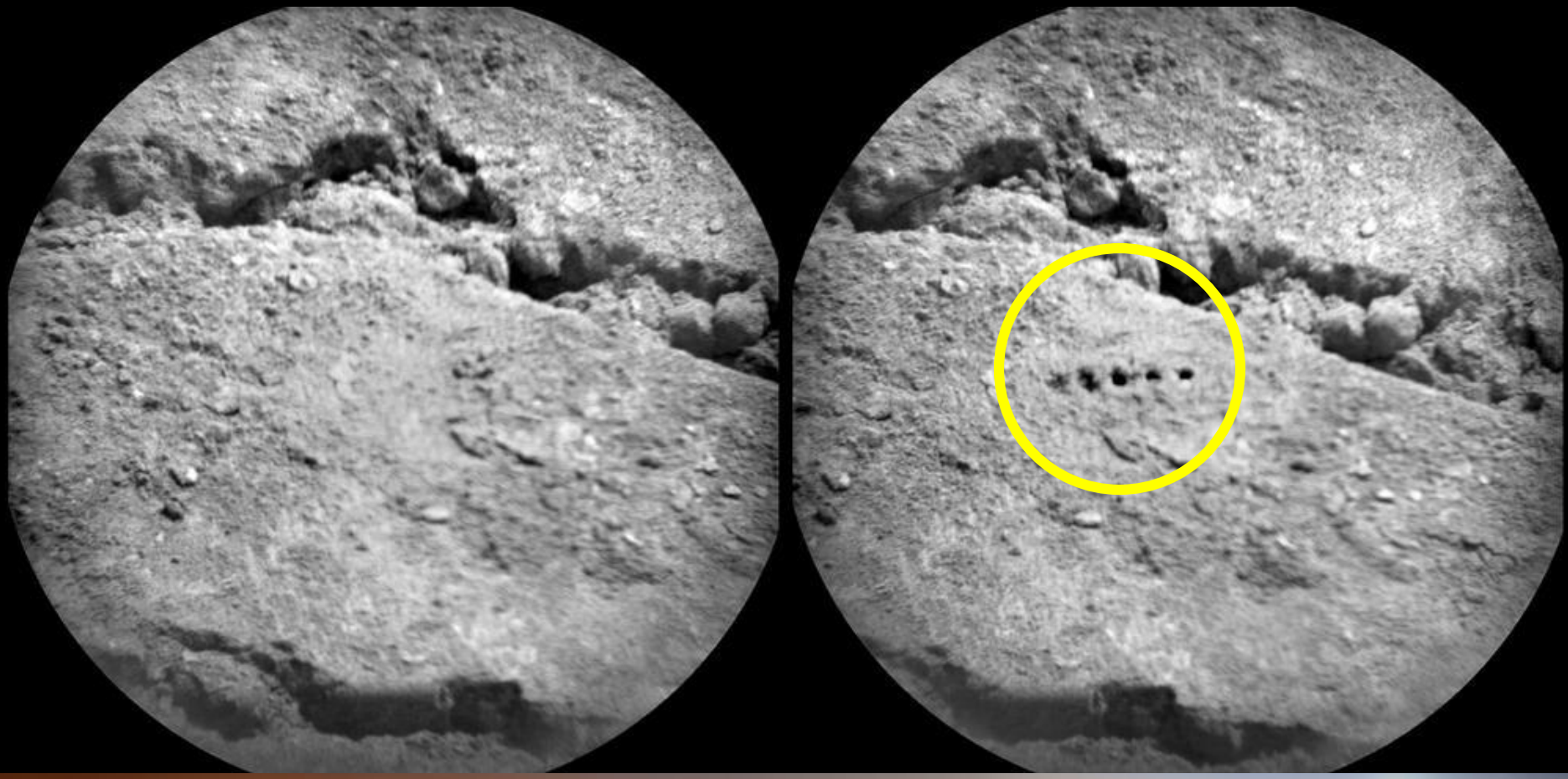
Getting the Context:
Zapping from far away.



SuperCam:
Before Enhanced ChemCam After



ChemCam Target: Beechey (Sol 19)
Power: 1 Gigawatt
5-spot raster, shots per spot: 50

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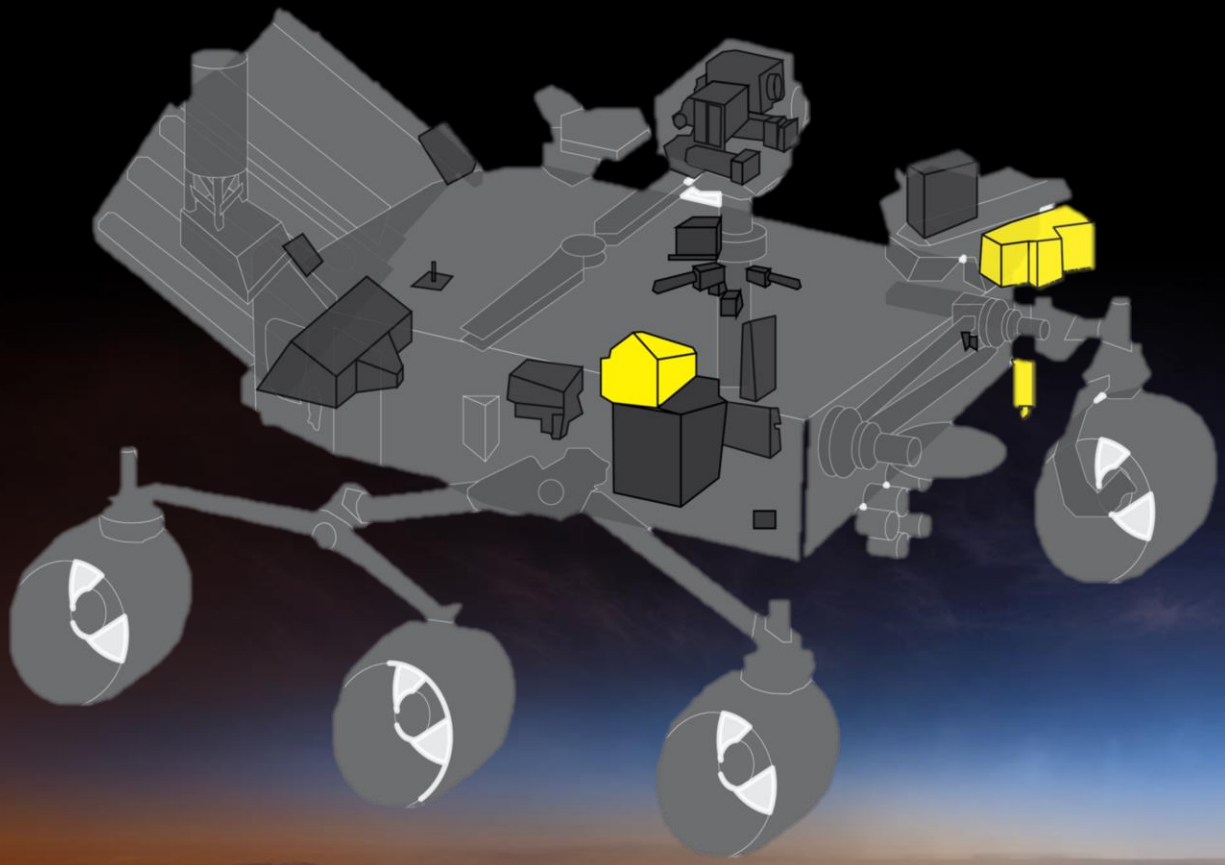
WATSON



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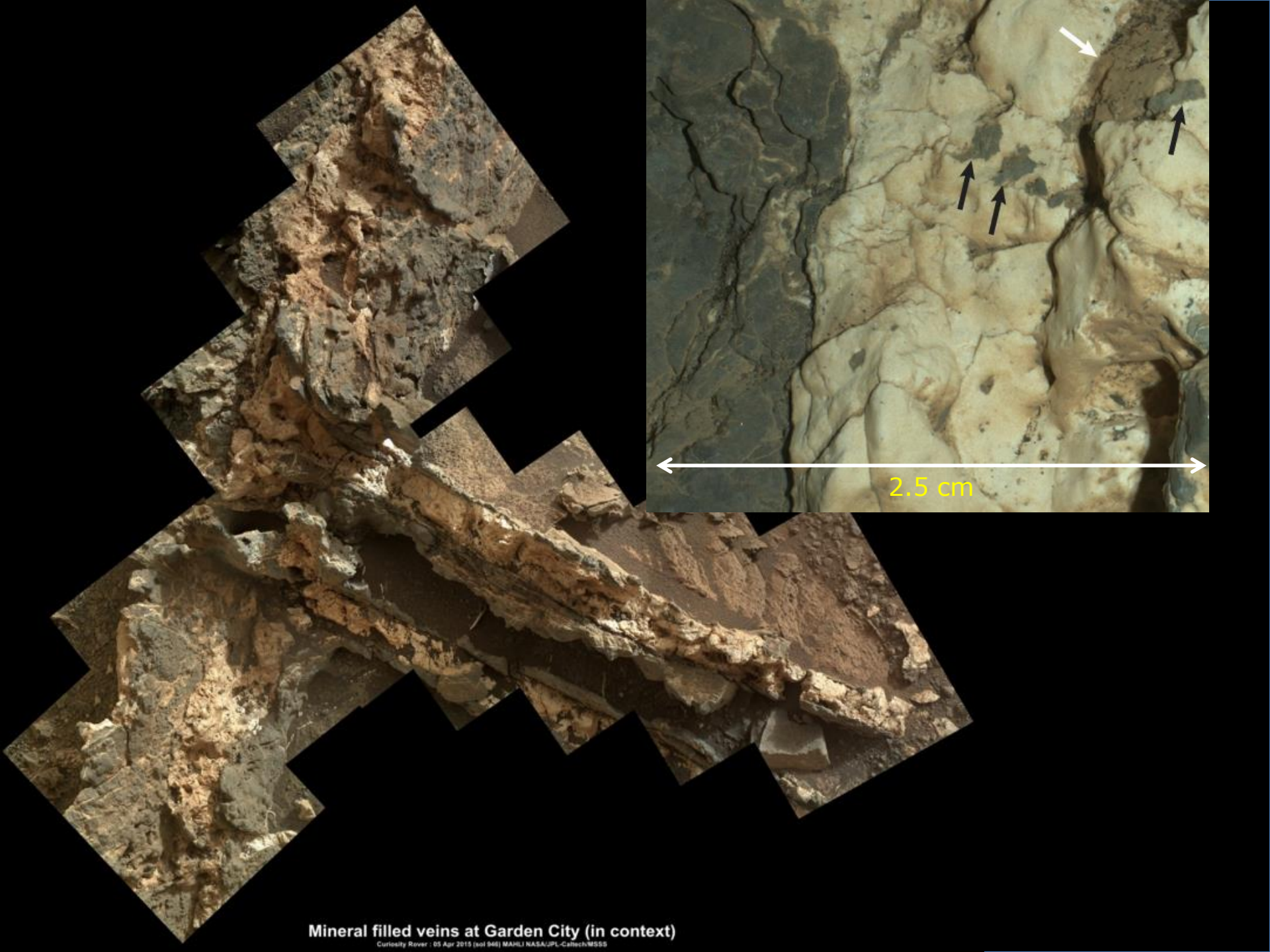
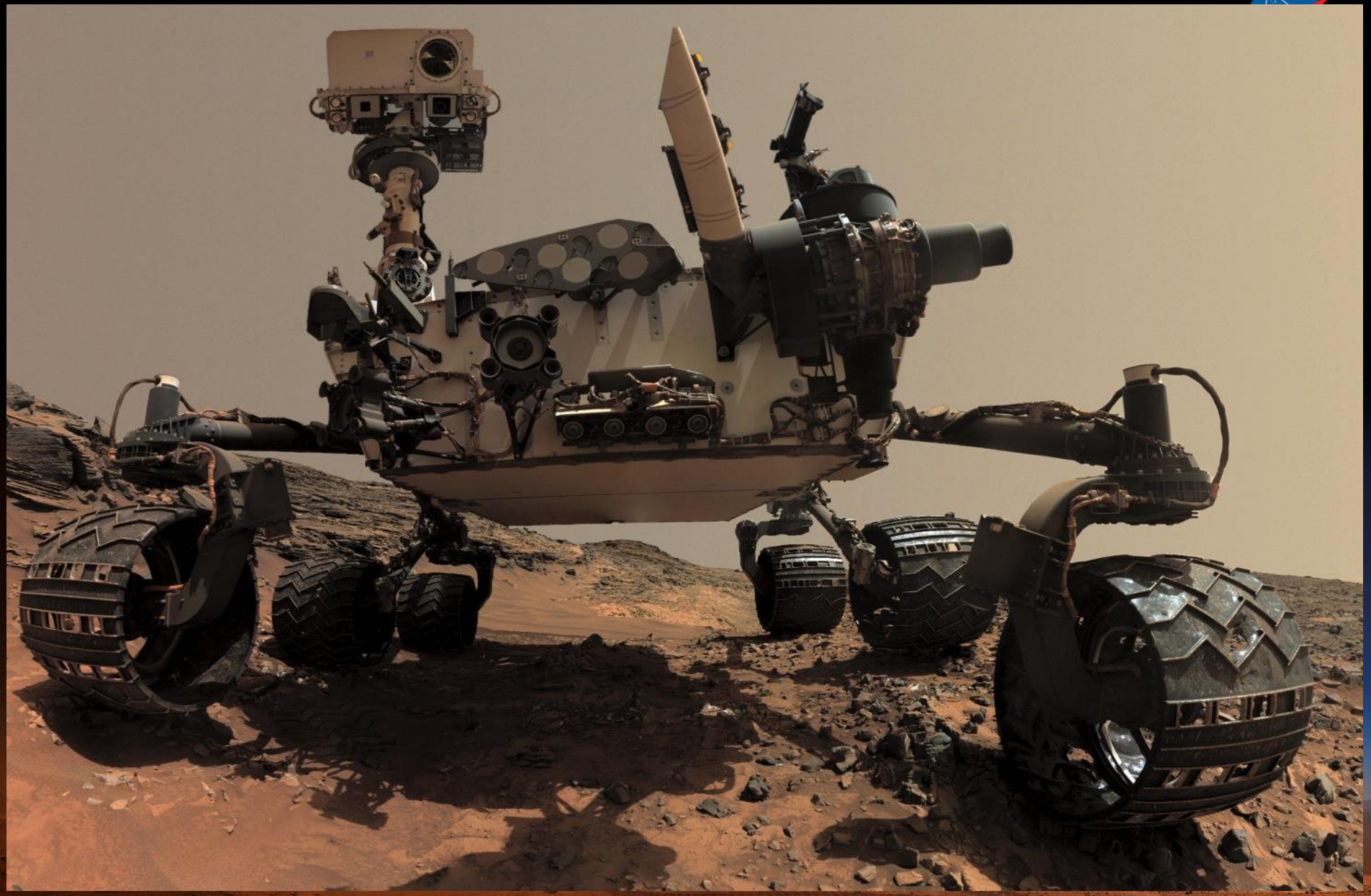
TRIPLET
30X-21mm



Mineral filled veins at Garden City (in context)

Curiosity Rover : 05 Apr 2015 (sol 946) MAHLI NASA/JPL-Caltech/MSSS



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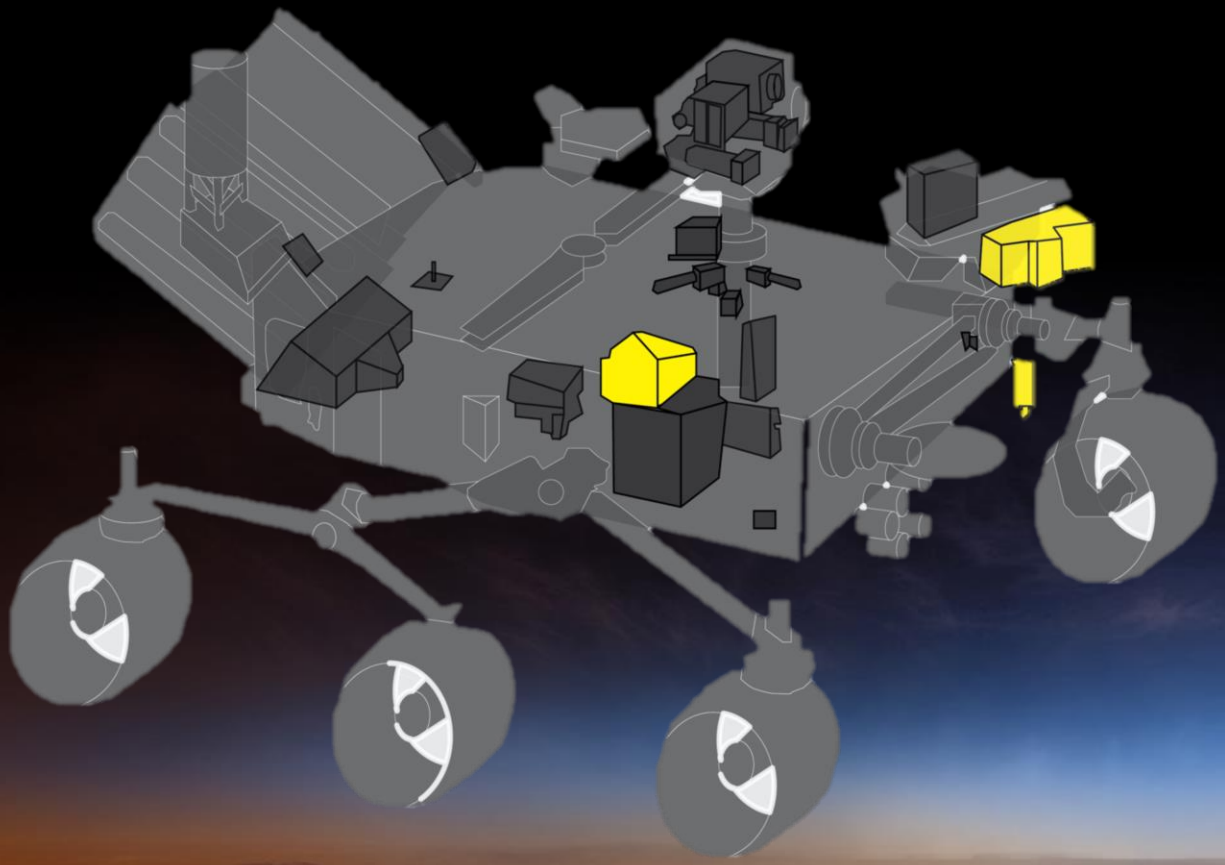
SHERLOC



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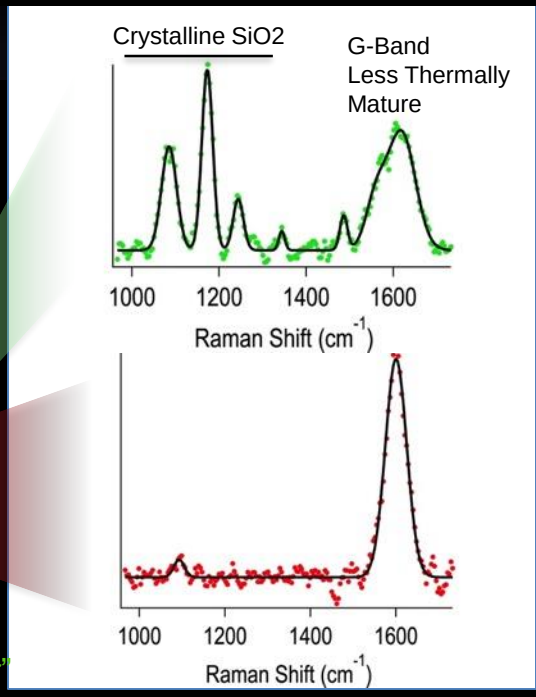
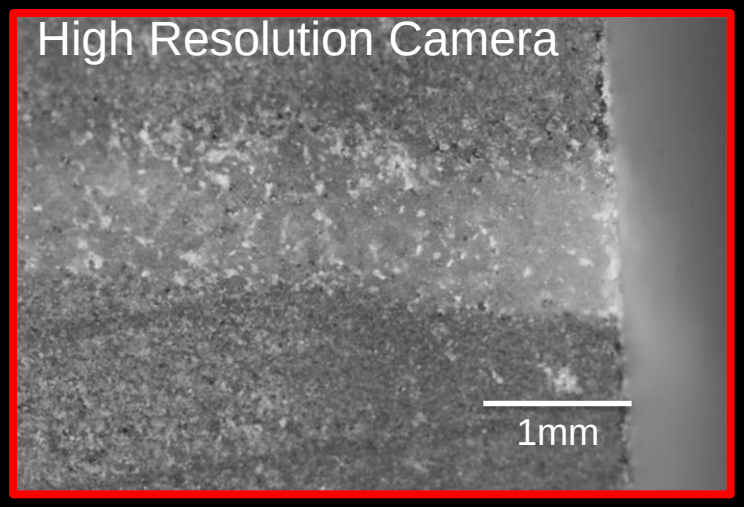
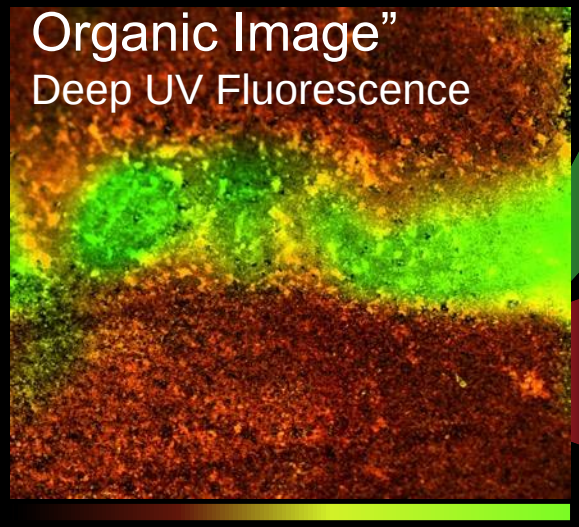
SHERLOC: Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals

SHERLOC's view through WATSON

Organic & Mineral Analyzer
Deep UV Raman

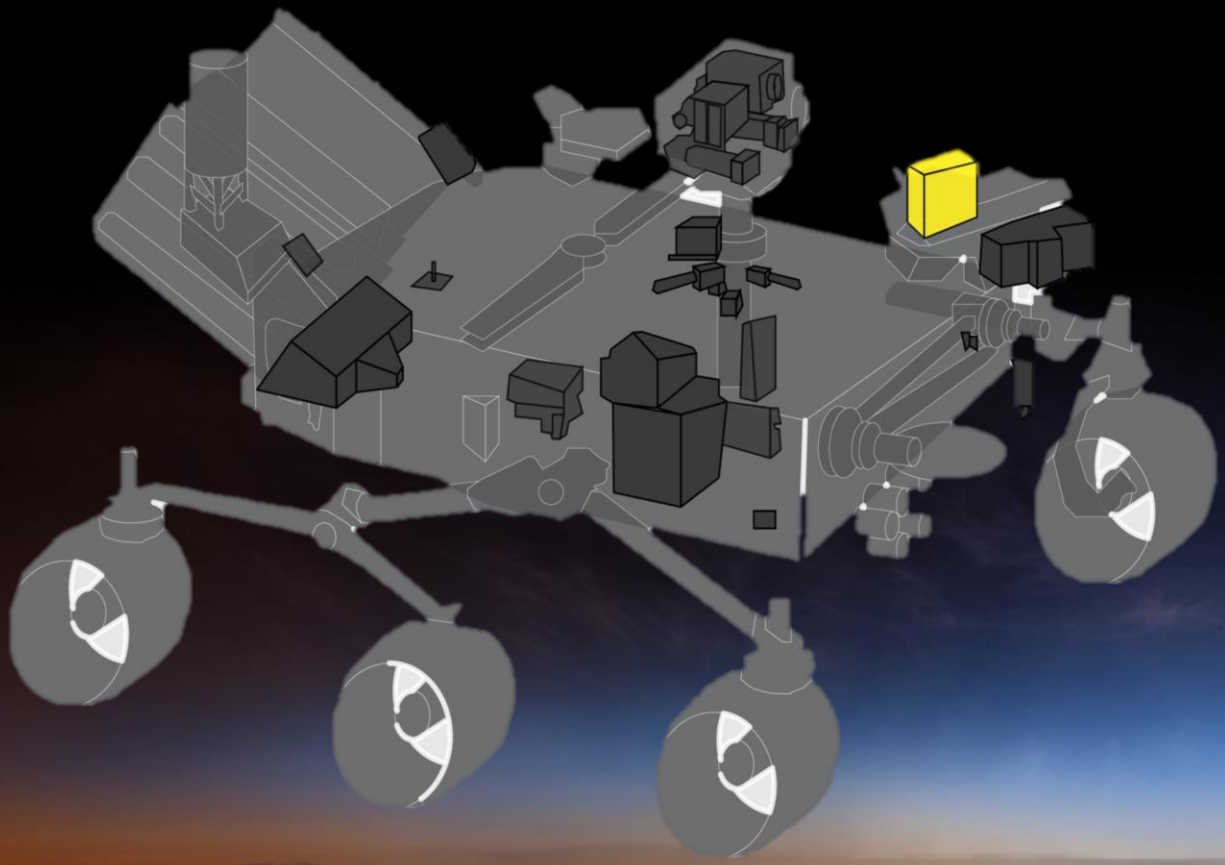






No Organics — Mature Org. (Heated) — "Younger" Organics

PIXL



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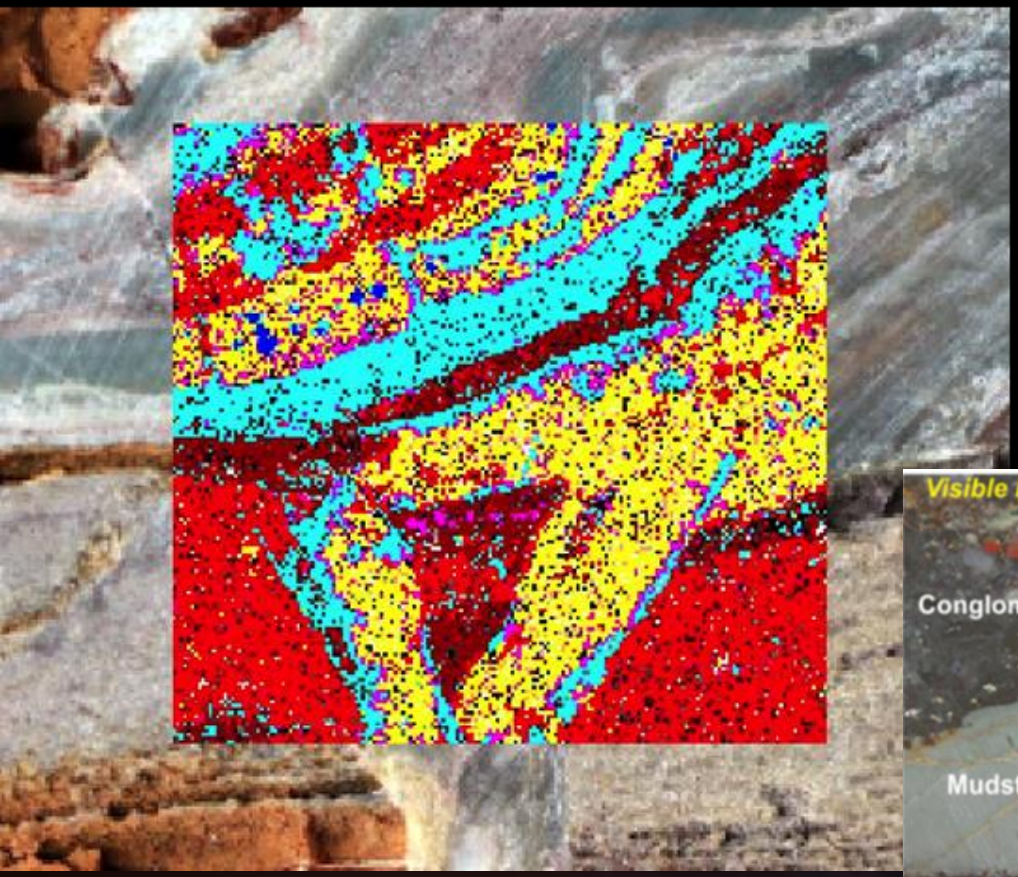
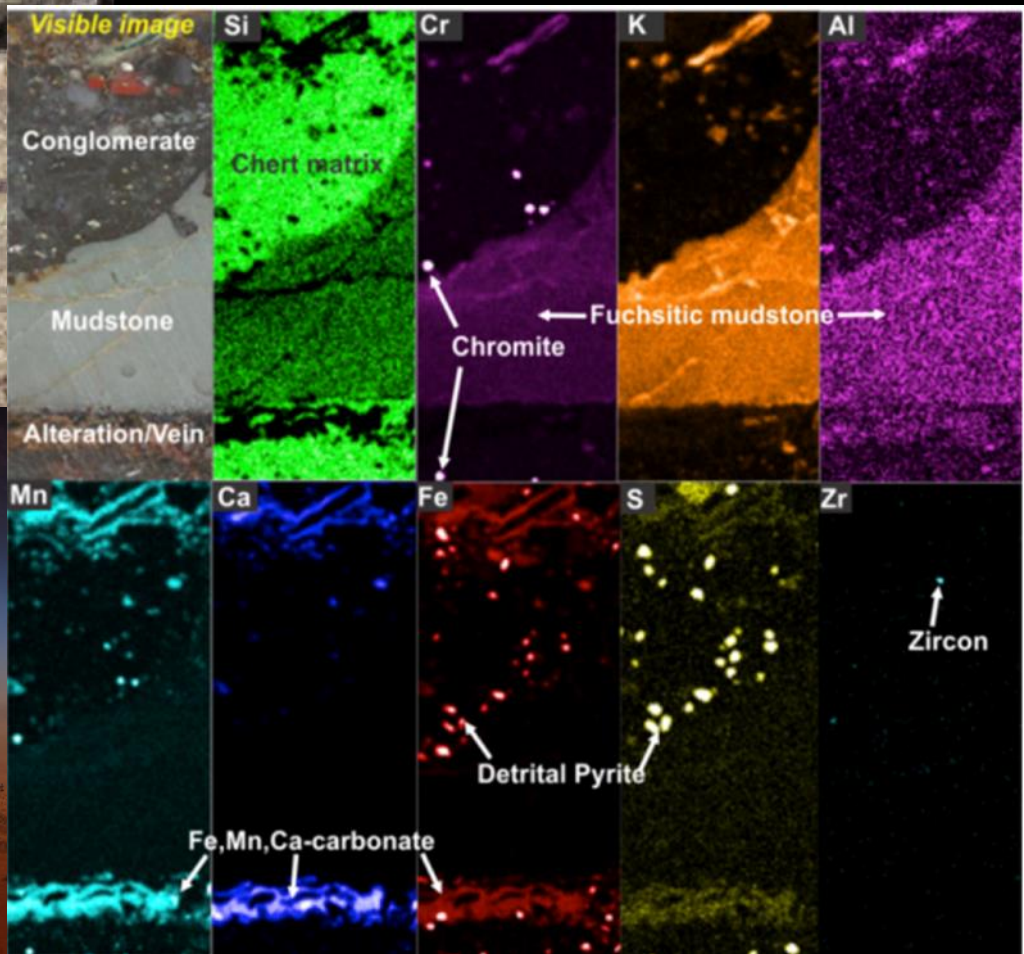
PIXL: Planetary Instrument For X-ray Lithochemistry





x-ray fluorescence tells you what elements the material is made out of

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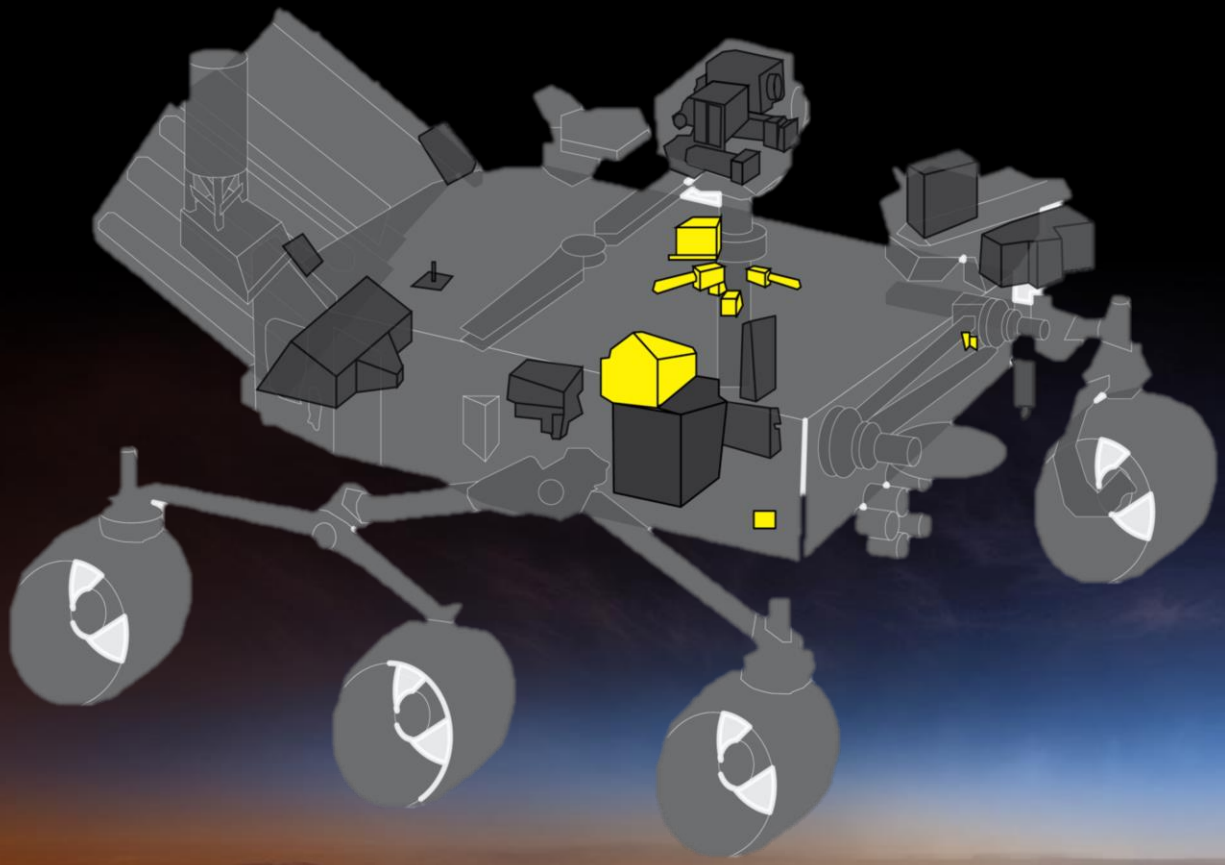
MEDA



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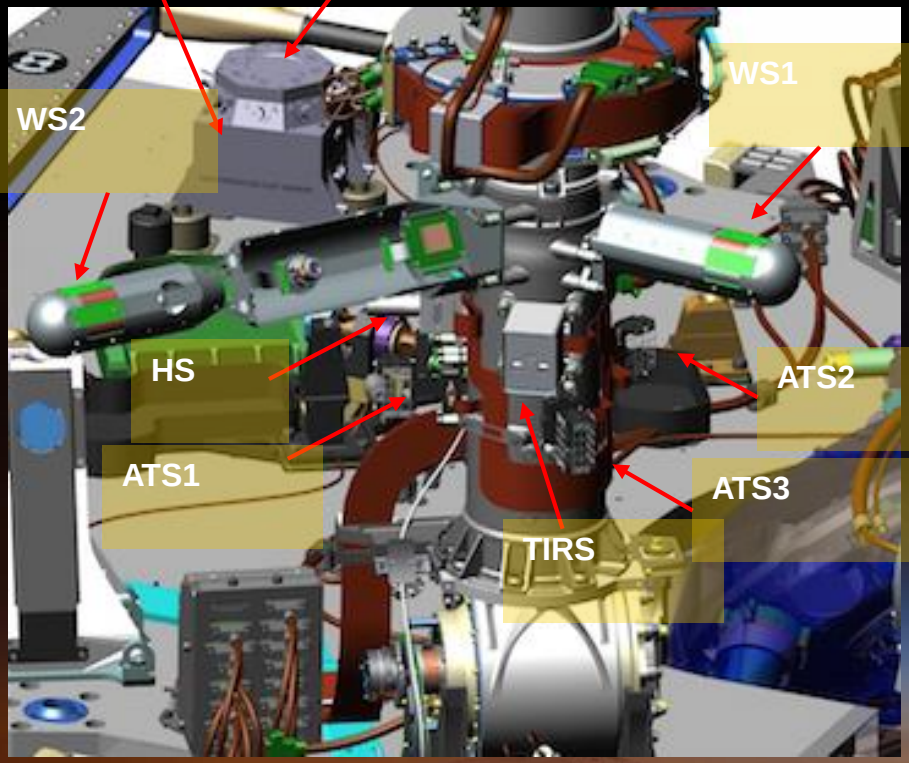
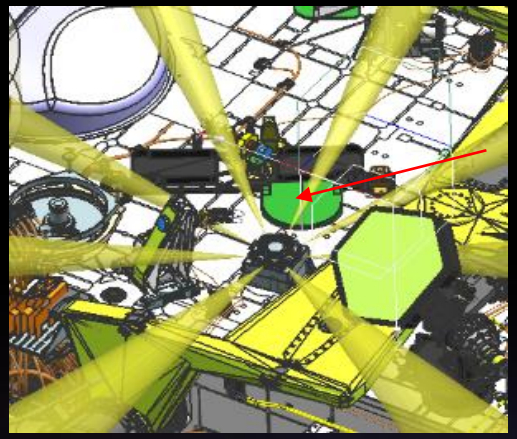
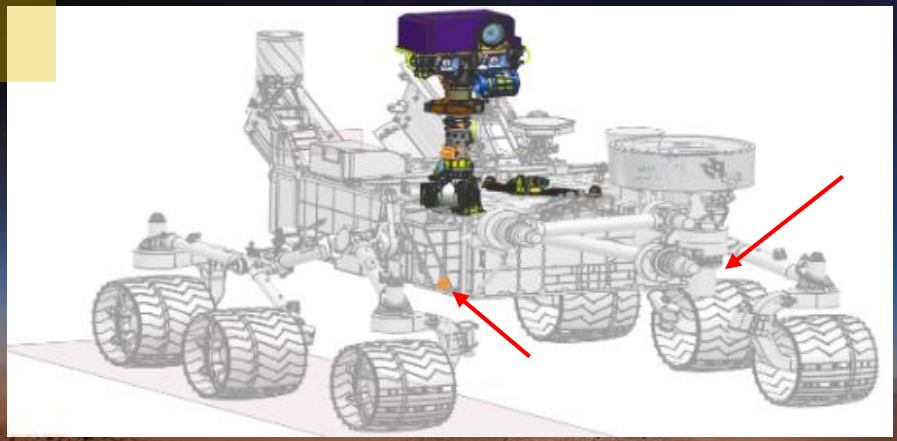
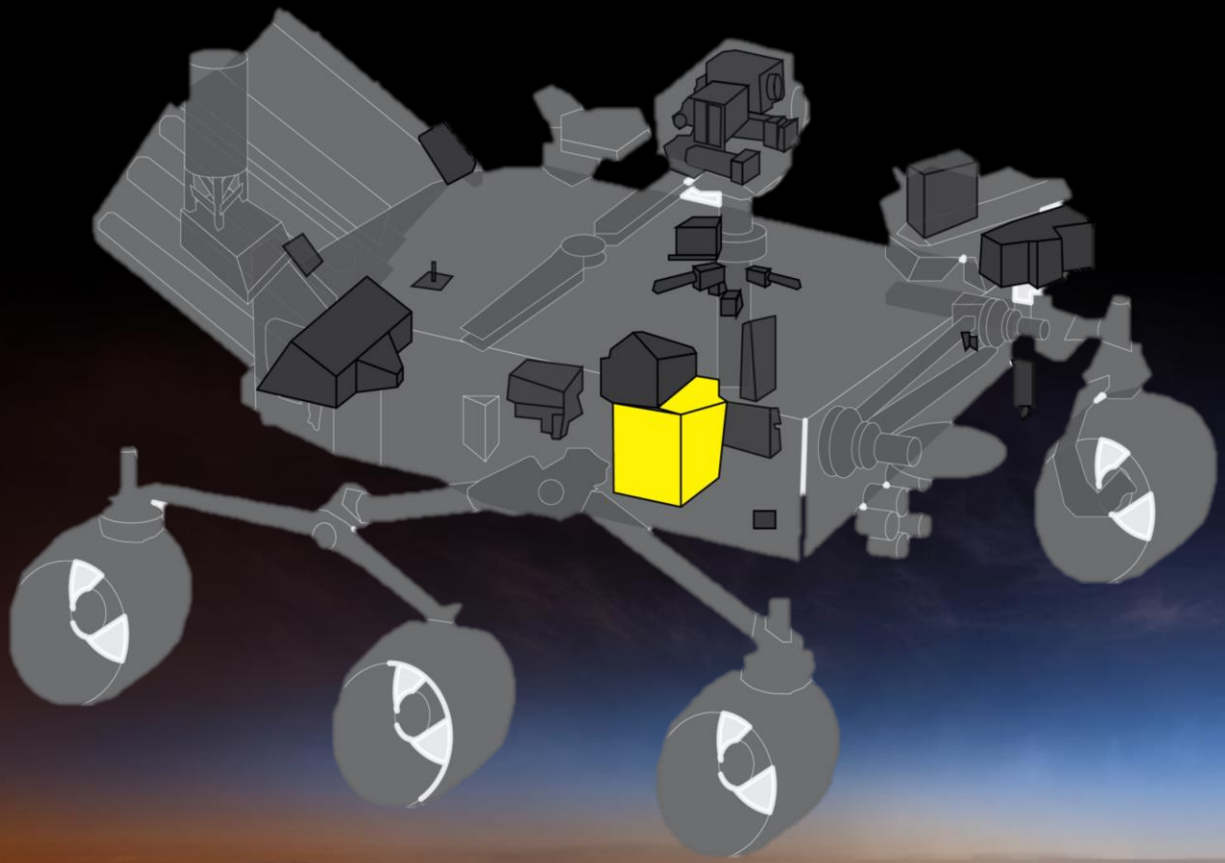
temperature, humidity, wind, dust analyzer







MOXIE



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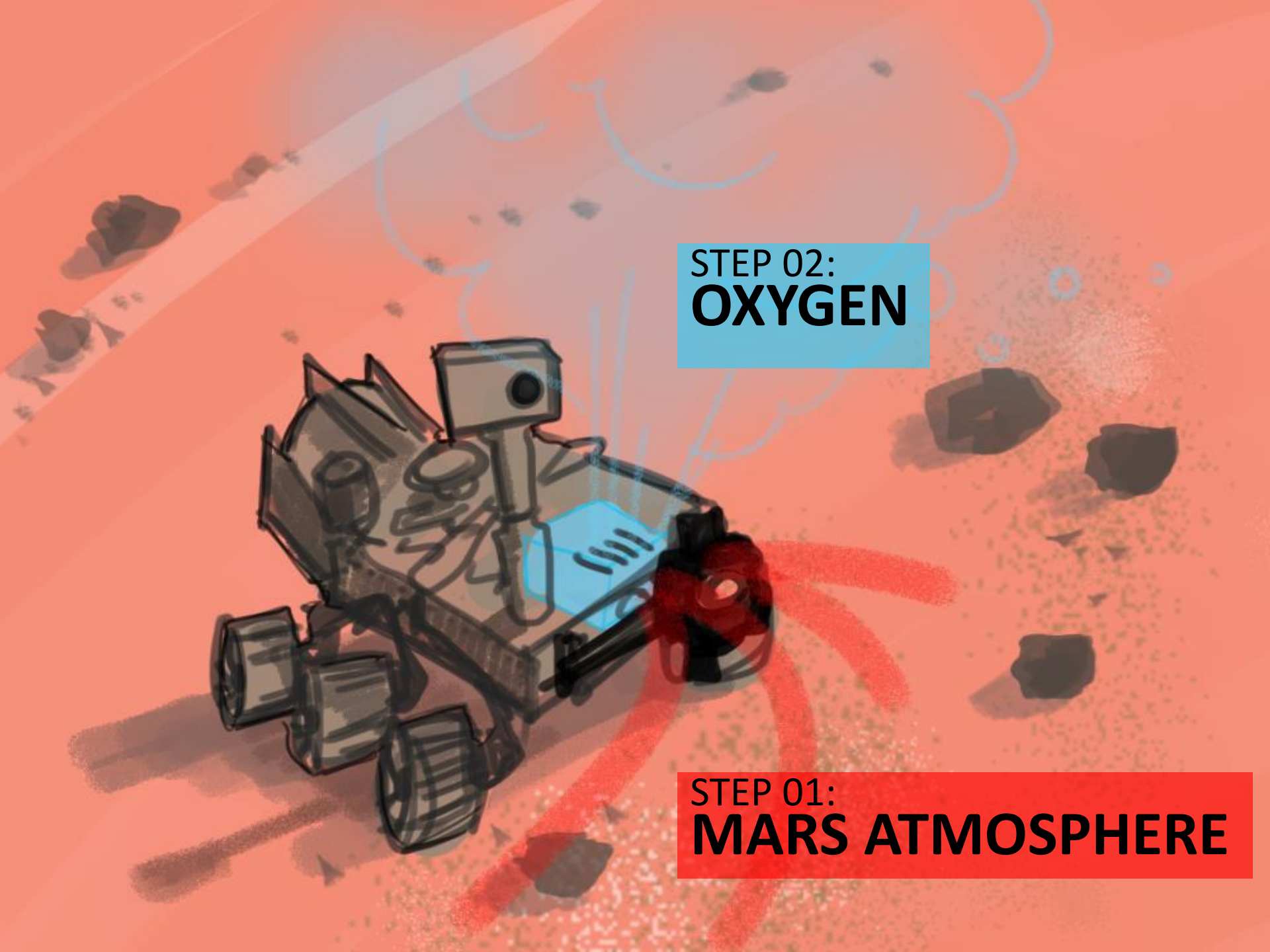
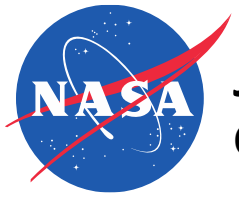
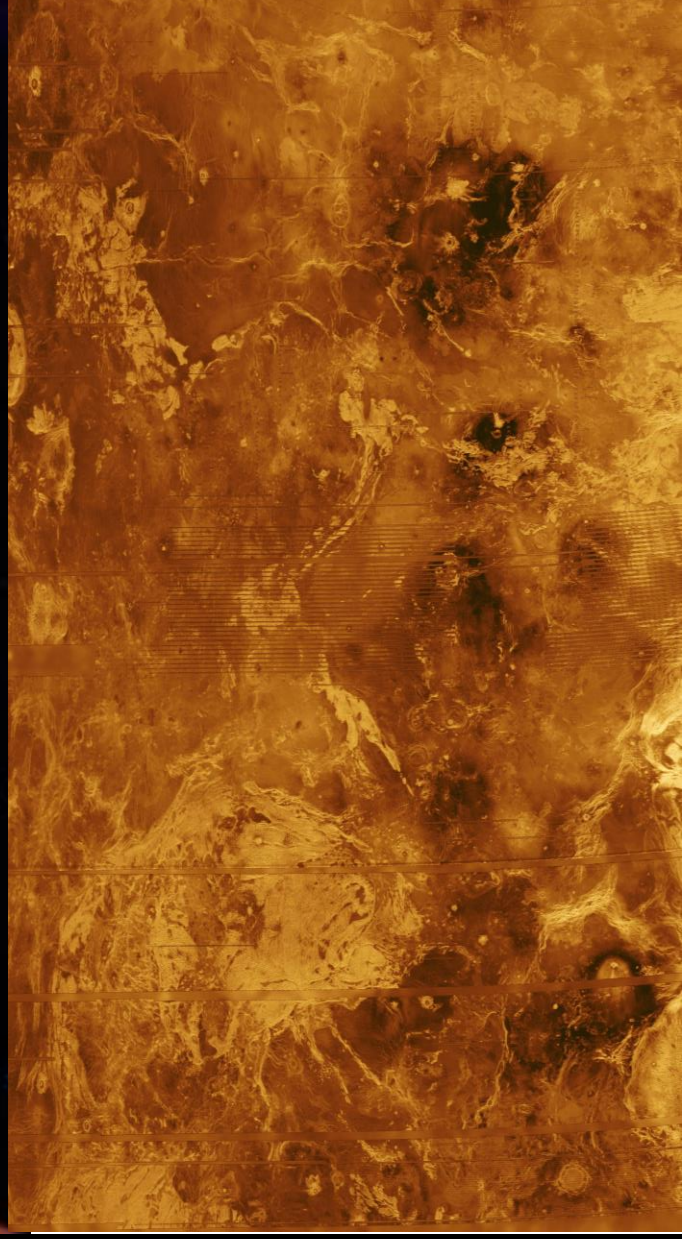
…a possible future…

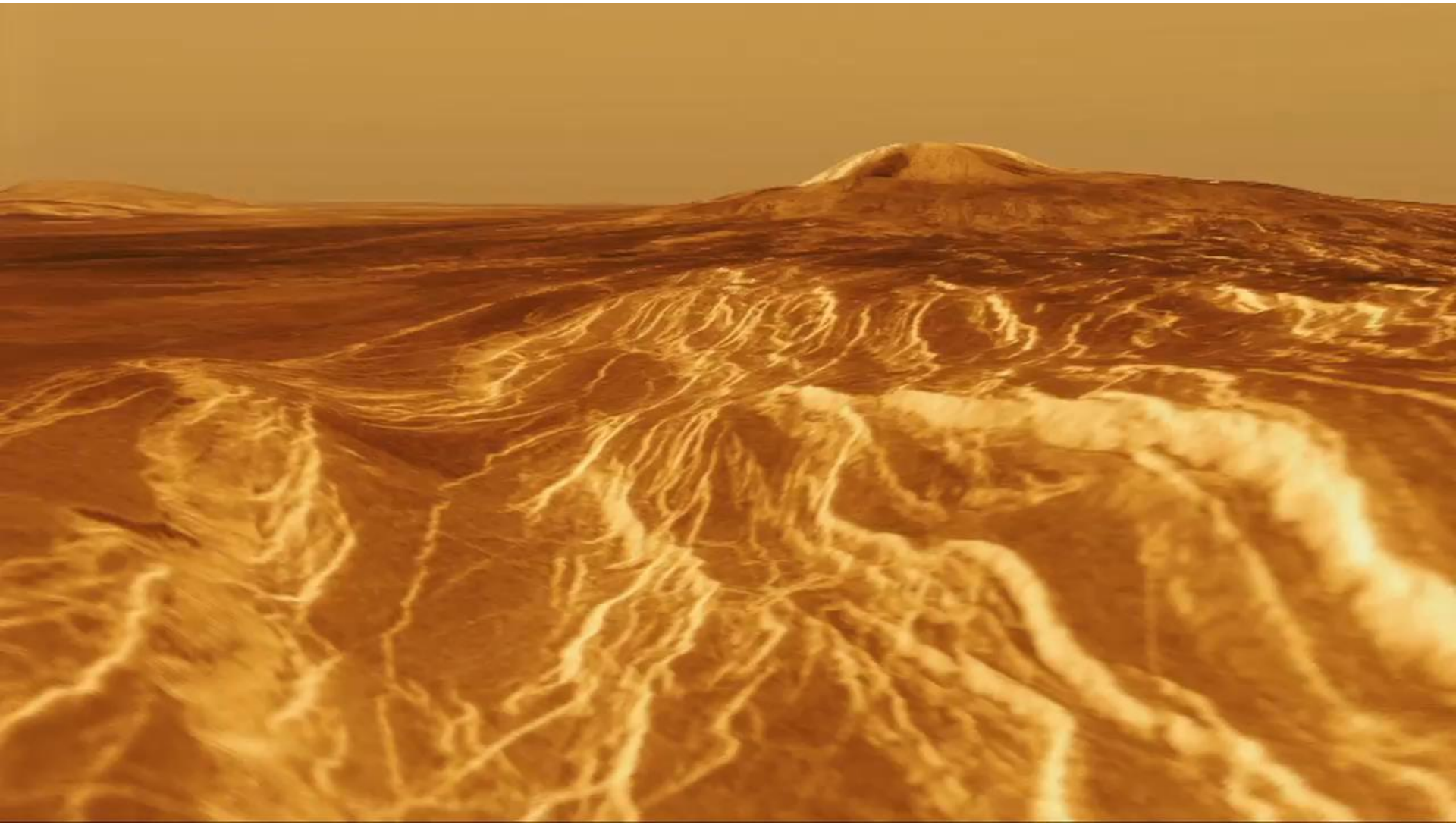

STEP 02:
OXYGEN
STEP 01:
MARS ATMOSPHERE

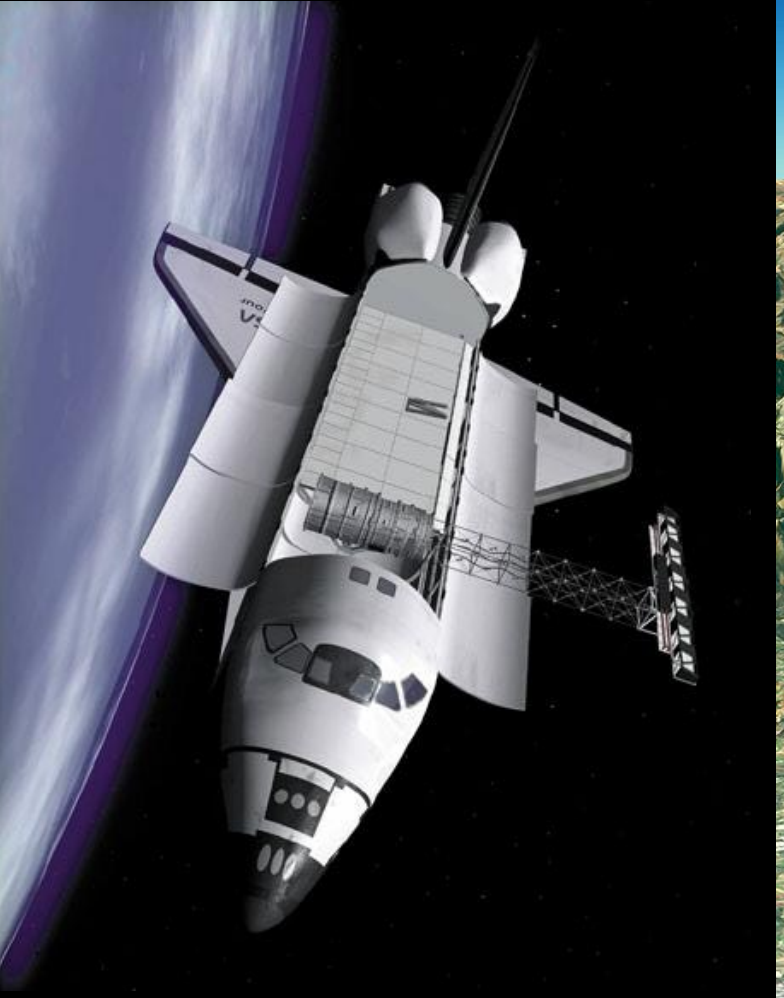


Jet Propulsion Laboratory
California Institute of Technology



1990 Magellan – Venus radar mapper





2000 Shuttle Radar Topography Mission (SRTM)